Effluent production and disposal in the South African dairy industry: A postal survey

JP Strydom[1,2], JF Mostert[2] and TJ Britz[1*]
[1]Dept. of Microbiology and Biochemistry, University of the Orange Free State, Bloemfontein 9300, South Africa
[2]Irene Animal Production Institute, Irene 1675, South Africa

Abstract

In South Africa, where water has been identified as the country's most important natural resource, the dairy industry is significant, both from a water intake and discharge point of view. The requirements of the dairy industry in relation to on-site effluent treatment were thus determined by means of a postal survey. Of the 247 questionnaires sent out, 81 were returned. The data obtained indicated that the respondents from the survey receive and process 70% of the total milk production in South Africa. A diverse range of effluents was described by the respondents. The larger factories generally discharge their effluents to municipal sewers resulting in high disposal costs. The majority of smaller factories and dairies dispose of their effluents by means of irrigation onto lands and pastures. A possible side-effect of this practice is of course ground-water pollution. Most of the respondents expressed a need for more information on the subject and a proposed project for the development of a biological effluent treatment procedure was supported by 49% of the respondents. These respondents represent 40% of the total milk volume processed in the country. The supportive respondents were also responsible for 84% of the reported municipal levies.

Introduction

Three years ago it was estimated that the South African dairy industry, with over 150 dairies, consumes approximately 4,5 x 10^6 m^3 water per annum (Water Research Commission, 1989). This makes the dairy industry a comparatively large water user. The specific water intake (water consumption : raw milk) ratio in the different dairy manufacturing sectors varies considerably and is dependent on the type of product and also on the individual management practices. The overall range varies between 1,4 and 9,5 with an overall mean of 3,6 (Water Research Commission, 1989).

Milk buyers annually receive and process approximately 1,86 x 10^9 ℓ of milk (Dairy Board, 1990). However, dairies also discharge large quantities of different effluents arising from milk processing, producing different milk products and from the cleaning processes. The ratios are dependent on the types of dairy products manufactured. It has been estimated that between 75% and 95% of the water intake emerges as effluent (Water Research Commission, 1989).

Milk and related products have exceptionally high chemical oxygen demand (COD) values (milk : 218 000 $mg \cdot \ell^{-1}$; skimmed milk : 100 000 $mg \cdot \ell^{-1}$; whey : 80 000 $mg \cdot \ell^{-1}$). The inevitable wastage of milk and milk products can contribute greatly to the pollution loads discharged. It has been estimated by Jones (1974) that for the USA the average COD of dairy effluents is approximately 3 800 $mg \cdot \ell^{-1}$. The average pollution load (as COD) for the South African dairy industry is not known but, since dairy practices in South Africa are similar to those practiced in the USA, it can be safely assumed that the average values would be similar.

Water management in the South African dairy industry for the purpose of effluent control is well documented (Funke, 1970; Water Research Commission, 1989). Significant recommendations have been made towards the in-house water management in the South African dairy industry (Water Research Commission, 1989). However, the nature of dairy effluents changes significantly when the water usage of a factory is reduced.

Currently, another problem found in the dairy industry is the disposal of the effluents. Until fairly recently, the issue of effluent disposal or treatment did not receive any serious consideration in the dairy industry. It is thus important that before any studies on the treatment and disposal of dairy factory effluents can commence, the need for such a study has to be evaluated. A comprehensive questionnaire on this subject was thus compiled and sent to all registered milk buyers in South Africa. This country-wide postal survey was also used to determine the scope of other effluent-related issues. These included the volumes of milk received, the products manufactured, the water usage, the expenditure associated with the effluent, the chemicals used in the factory, and the degree of effluent-awareness of the factory's management. This paper thus reports on the results from this national postal survey on dairy effluents.

Experimental

The questionnaire, sent to the 247 milk buyers registered during 1991 (Nell, 1991), covered the following aspects:

- Milk volume received
- Products manufactured
- Water usage
- Chemicals used in the dairy or factory
- Effluent volume and strength
- Effluent treatment prior to disposal
- Effluent disposal
- Economics related to effluent disposal
- Interest in the intended future effluent treatment and/or disposal projects.

In the questionnaire, specific questions were used to determine figures on daily rates. These included daily water usage, milk reception volume and effluent discharge volume. The answers were converted, where applicable, to yearly rates by multiplying with a factor of 264, assuming a month consisted of 22 work-days.

*To whom all correspondence should be addressed.
Received 9 October 1992; accepted in revised form 12 February 1993.

TABLE 1
MANAGEMENT AWARENESS OF EFFLUENT VOLUMES, POLLUTION VALUES AND COSTS OF EFFLUENT DISPOSAL AS INDICATED IN A POSTAL SURVEY REPRESENTING 70% OF ALL MILK RECEIVED IN SOUTH AFRICA

	Group*1	Group 2	Group 3	Group 4
Number of respondents	**17**	**10**	**21**	**25**
Effluent volumes				
Awareness (%)**	100	90,0	81,0	80,0
Minimum ($k\ell \cdot d^{-1}$)	2,5	44	0,25	0,04
Maximum ($k\ell \cdot d^{-1}$)	519	424	3 000	20
Average ($k\ell \cdot d^{-1}$)	134	212	401	3,5
Pollution values (chemical oxygen demand)				
Awareness (%)**	23,5	50,0	19,0	0
Minimum ($mg \cdot \ell^{-1}$)	1 000	641	1 000	-
Maximum ($mg \cdot \ell^{-1}$)	2 100	9 700	7 000	-
Average ($mg \cdot \ell^{-1}$)	1 360	3 500	3 400	-
Disposal costs				
Awareness (%)**	35,3	60,0	61,9	16,0
Minimum ($R \cdot a^{-1}$)	5 000	6 000	900	84
Maximum ($R \cdot a^{-1}$)	8 000	60 000	300 000	8 000
Average ($R \cdot a^{-1}$)	28 000	34 600	91 000	2 300

* Group 1: Cheese manufacturers; Group 2: Milk powder manufacturers; Group 3: Large fresh milk producers; Group 4: Small fresh milk producers.

** Number of group members, who indicated effluent volume, effluent COD and effluent disposal cost, expressed as a percentage of the total for each group.

The 247 registered milk buyers included all the manufacturers of dairy products and fresh milk distributors, but not ice-cream as the manufacture of the latter does not involve fresh milk. All addresses were supplied by the Dairy Services Organisation and pre-paid envelopes were included for the convenience of the respondents. The respondents were allowed 2 weeks to return the completed questionnaire. This deadline was extended in order to obtain as many replies as possible.

Results

Respondents

In response to the postal survey, 81 replies were received, of which 73 were found suitable for data processing. The remaining 8 were unsuitable due to insufficient answers to the questions - some even were returned completely blank. This represents a response of only 29,6% of the total sent out. However, these respondents receive and process 70% of the total milk production in South Africa, calculated by using national figures published by the Dairy Board in 1990. This figure was also calculated using a 22 workday month. The respondents thus represent the largest and probably the most important members of the South African dairy industry.

The respondents manufacture the complete range of dairy products and therefore the returned questionnaires could be divided into 4 groups representing the:

- Cheese manufacturers (17 respondents)
- Milk powder manufacturers (10 respondents)
- Fresh milk manufacturers - milk reception greater than 10 $k\ell \cdot d^{-1}$ (21 respondents)
- Fresh milk manufacturers - milk reception less than 10 $k\ell \cdot d^{-1}$ (25 respondents).

In Table 1 the results of the survey, relating to the management awareness of effluent volumes, pollution values and costs of effluent disposal, are shown for each individual group. Figures 1 and 2 respectively depict the specific water consumption and the product losses in relation to the milk volume received for each of the 4 respondent groups.

Cheese manufacturers

The cheese manufacturers produce soft and/or hard cheese varieties. Respondents in this group indicated that cheese was the only dairy product manufactured and thus, the volumes of milk received varied considerably. Milk reception volumes within this group, varied between 1,2 and 197,0 $k\ell \cdot d^{-1}$, with an average of 48,0 $k\ell \cdot d^{-1}$. The average water usage of the cheese manufacturers was 122 $k\ell \cdot d^{-1}$, with the highest usage of 380 $k\ell \cdot d^{-1}$ recorded by a milk buyer receiving 104 $k\ell \cdot d^{-1}$ milk on average.

The effluent awareness of all 17 cheese producers was notable in that all the respondents indicated what their effluent volumes were. Two producers dispose of their effluent by land irrigation, the effluent volumes being 130 and 45 $k\ell \cdot d^{-1}$, respectively. The rest of this group dispose of their effluent into local municipal sewers. Only 6 of the respondents reported expenditure

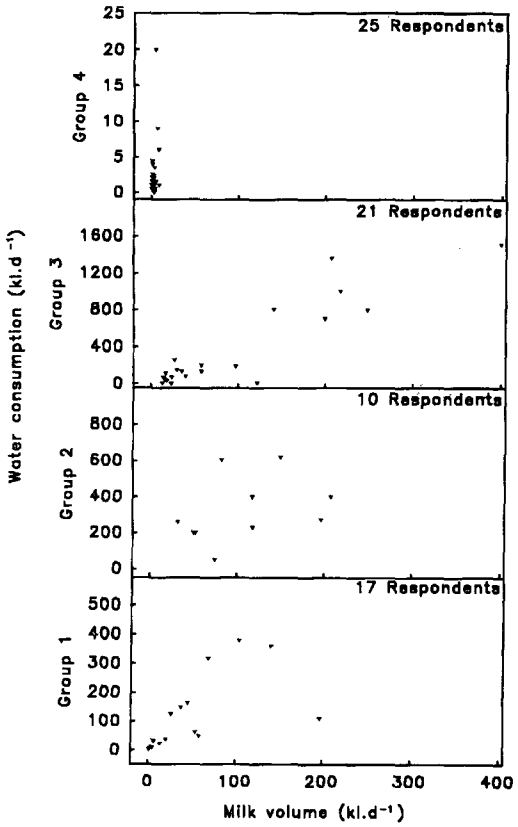

Figure 1
Comparison between the water consumption and raw milk volume ratios (v/v) of the 4 groups. (Group 1: Cheese manufacturers; Group 2: Milk powder manufacturers; Group 3: Large fresh milk producers; Group 4: Small fresh milk producers. ▼ = individual respondent.)

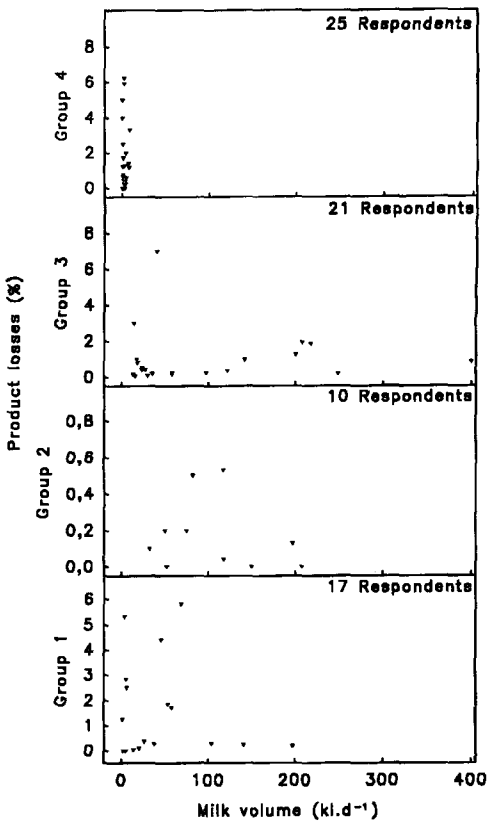

Figure 2
Product losses expressed as a percentage of the raw milk volume received. (Group 1: Cheese manufacturers; Group 2: Milk powder manufacturers; Group 3: Large fresh milk producers; Group 4: Small fresh milk producers. ▼ = individual respondent.)

associated with effluent disposal which, on average, represents a yearly total of R170 000 in terms of municipal levies and taxes.

Only 4 respondents indicated the pollution properties of their factory effluents, expressed as chemical oxygen demand (COD, as $mg \cdot \ell^{-1}$), pH and temperature. Furthermore, only one respondent recorded the suspended solids content (230 $mg \cdot \ell^{-1}$) of the specific factory.

The COD levels as recorded by the respondents varied from 1 000 to 2 100 $mg \cdot \ell^{-1}$, with an average of 1 360 $mg \cdot \ell^{-1}$. The effluent pH varied from pH 5,0 to pH 10,0 and the temperature, as recorded by the respondents, varied from 10° to 30°C. Incidentally, one of the effluents used for irrigation had an average COD value of 1 150 $mg \cdot \ell^{-1}$, pH 5,0 and suspended solids content of 230 $mg \cdot \ell^{-1}$.

Milk powder producers

The 10 milk powder manufacturers indicated that milk powder was their only product of manufacture. As can be expected, all milk powder factories are fairly large operations, with milk reception volumes ranging from 32 to 200 $k\ell \cdot d^{-1}$. The water usage ranged from 324 to 620 $k\ell \cdot d^{-1}$.

Nine of the respondents of this group indicated their factories' estimated effluent volume. This ranged from 44 to 424 $k\ell \cdot d^{-1}$. Three of the milk powder producers disposed of their effluents, which totalled 480 $k\ell \cdot d^{-1}$, onto land or pastures. No indication of the COD values was given by these respondents. In contrast, 5 of the remaining respondents clearly indicated the COD values of their effluents, which ranged from 641 to 9 700 $mg \cdot \ell^{-1}$, with an average of 3 500 $mg \cdot \ell^{-1}$. The pH of these effluents ranged from 4,5 to 9,5. Only 6 of the respondents recorded the costs associated with effluent disposal, these ranging from R6 000 to R60 000, with a total of R207 000 per annum for the group as a whole.

Fresh milk producers (reception volumes greater than 10 $k\ell \cdot d^{-1}$)

The 21 respondents included in this group produced pasteurised milk, UHT milk, sterilised milk, evaporated milk, condensed milk, milk powder, pasteurised cream, soft and hard cheeses, process cheese, butter, cultured buttermilk and buttermilk powder, evaporated whey and whey powder, custards, desserts and different varieties of yoghurt.

The milk reception volumes varied from 13,25 to 400,0 $k\ell \cdot d^{-1}$. Their reported water usage varied from 2 to 1 514 $k\ell \cdot d^{-1}$. All use municipal water, and 17 indicated that their effluents are received by their local municipal sewage treatment works. The remainder gave no indication as to how their effluents were disposed of.

Although only 4 respondents recorded their effluents' COD values, ranging from 1 000 to 7 000 $mg \cdot \ell^{-1}$, 13 indicated the costs associated with the disposal of their effluents. The expenditure ranged from a mere R900 to R300 000 per year, with a total of R1 171 000 for this group as a whole.

TABLE 2
THE POSITIVE INTEREST (AS % OF RESPONDENTS) EXPRESSED BY THE SOUTH AFRICAN DAIRY INDUSTRY IN TERMS OF RESEARCH AND TRAINING OPTIONS

	Group*1	Group 2	Group 3	Group 4
Proposed project	59%	50%	60%	32%
Proposed seminar	65%	90%	55%	24%
Effluent analyses	35%	20%	35%	24%

* Group 1: Cheese manufacturers; Group 2: Milk powder manufacturers; Group 3: Large fresh milk producers; Group 4: Small fresh milk producers.

Fresh milk producers (reception volumes less than 10 kℓ·d^{-1})

Even though Groups 3 and 4 differed with regard to milk reception volumes, Group 4 respondents indicated the production of only 4 dairy products, namely pasteurised milk, pasteurised cream, yoghurt and fruit juice blends.

Twenty-five respondents were grouped in this category, with milk reception volumes varying from 200 to 9 000 ℓ·d^{-1}. Many of these respondents (10) receive milk in cans which are then washed on site. Furthermore, most respondents indicated substantial product losses ranging between 0,6 and 6,25%.

The water usage of the respondents of this group varied from 400 ℓ·d^{-1} to 20 kℓ·d^{-1}. Not one of these respondents indicated the pollution value of their effluents. For the group as a whole, the total reported effluent-related expenditure amounted to only R9 200.

Support for the intended project

The interest expressed by the respondents in the intended project and their interest in a proposed seminar to be held on this subject are summarised in Table 2. Table 2 also shows which of the respondents are interested in having their factory's effluents analysed.

Discussion

The frankness and co-operation of the respondents to the postal survey is indeed to the credit of the local dairy industry, bearing in mind the sensitivity of the subject. Even though only 81 of the 247 questionnaires were returned, the response is still significant since it represents 70% of all milk received and processed in South Africa. The results obtained from this survey give valuable insights into the situation of the South African dairy industry. It also highlighted several problems encountered by the industry. These include product losses, water usage, and effluent disposal.

Overall results

By dividing the respondents into 4 groups, data interpretation was simplified but certain important results are still obscured. These include the high cost of effluent disposal, an item on which the respondents annually spend R1,5 million. Since this is only representative of 30% of the registered milk buyers, the total amount spent on effluent disposal by the dairy industry in South Africa would of course be much higher.

Moreover, by dividing the respondents into 4 groups, one or more groups might be singled out artificially. The 4-group division, presented in Table 1 and representing 70% of the milk produced in South Africa, shows that the smaller fresh milk factories are not well informed about their factories' effluent situation and impact. However, when the data are presented differently (Figs. 1 and 2), it is obvious that equally alarming tendencies, such as high product losses and excessive water usage, are found, not only among the smaller factories but also at some of the large dairy factories. When the data are examined closely, ideal product loss and water usage values are obvious among some of the smaller dairy operations. However, as also found in the NATSURV 4 survey, larger dairies are generally more efficient in their water management than smaller ones although it is not only the smaller dairies who need to review thier water management practices.

NATSURV 4 survey

In 1989 the Water Research Commission published the results of the National Industrial Water and Waste-water Survey on the water and waste-water management in the dairy industry, the fourth in the NATSURV series. This survey, representing 19 dairies, summarised the major steps involved in the production of the various milk products, the water intake, effluent and solid wastes produced by the South African dairy industry. In this survey several conclusions and recommendations were also made in terms of the water intake, as well as potential methods of reducing water intake, effluent volume and effluent load. Several recommendations were also made concerning effluent treatment and potential future research.

A comparison of the NATSURV 4 survey data and the data from this study is summarised in Table 3. The dairies which took part in the NATSURV 4 survey represented 53% of the raw milk produced in 1986. In contrast, the current survey represents 70% of the raw milk produced in 1990. However, the respondents to the current survey only make up 30% of the total number of dairies. This indicates that in both surveys a small number of very large dairies accounts for the vast majority of milk processed in South Africa. From Fig. 1, it is seen that only 14 of the 81 respondents receive more than 100 kℓ·d^{-1} raw milk.

Further comparison between the current data and the NATSURV 4 data reveals an impossibly wide range (0,01 to 9,5) of specific water consumption values on the part of the current survey. This is probably due to an underestimation of water usage on the part of certain individual respondents. The diversity of the current survey's results indicates doubts about the accuracy of the data submitted by the dairies. This must also be taken into consideration when comparing the current results to

TABLE 3
COMPARISON OF CURRENT DATA WITH DATA FROM THE NATSURV 4 SURVEY

	Current survey	NATSURV 4 survey
Survey year	1991	1986
Number of dairies surveyed	73	19
Total number of dairies	247	150+
Total water consumption of respondents	3 700 000 $m^3 \cdot a^{-1}$*	4 500 000 $m^3 \cdot a^{-1}$
Milk volume represented by respondents**	70%	53%
Water intake : raw milk ratio (v/v)	0,01 - 9,5	1,4 - 9,5
Water intake emerging as effluent	13% - 96%	75% - 95%

* Assuming 22 workdays per month
** Calculated from 1990 Dairy Board figures

the NATSURV 4 survey. It also appears as if the effluent volumes are underestimated by some respondents in the current survey. It is, for example, highly unlikely that only 13% of a dairy factory's water usage would end up as effluent, as this means that the remaining 87% of the water consumed by the factory is either lost through evaporation or ends up in the final product sold to the public. It is however, possible that ice-cream manufacturers may have substantially lower effluent volume to water consumption values, since water is included in their final product. However, no ice-cream manufacturers were included in this survey since milk powder, instead of fresh milk, is used for the production of ice-cream. The NATSURV 4 survey did include ice-cream factories, and this might explain the wide reported range of water usage emerging as effluent.

Water consumption

The specific water consumption of a dairy factory is the amount of water used to process one liter of raw milk. In the literature, amounts are quoted ranging from 0,5 to 20 ℓ per kg of milk processed, but according to Hiddink (1990) an amount of 0,5 to 3,0 ℓ is generally acceptable. Recommendations on the specific water consumption of a factory in the NATSURV 4 survey (Water Research Commission, 1989), vary according to the type of product manufactured. In Fig. 1 the specific water consumption of the respondents from this survey is illustrated. Compared to the recommendations from the NATSURV 4 survey, the local dairy industry consumes excessive water. The target values in the NATSURV 4 survey vary from 1,1 ℓ for milk packaged in sachets, to 6,3 ℓ for cultured products. A value of 20 m^3 water per ton of cheese produced, is also recommended, and assuming a cheese yield of 10%, this translates to 2,0 ℓ water per liter of milk used for cheese production. Incidentally, the high water consumption may explain why the local effluents have COD values lower than the average COD values reported by Jones (1974) for the USA. However, many respondents from this survey appear to have a very low specific water consumption value, and in several instances the indicated values are impossibly low. This is either due to a misunderstanding or due to a deliberately low indication of their water consumption.

Product losses

Considering the reported product losses, it is obvious from Fig. 2 that the bigger milk processors appear to control product losses more successfully. Product losses should range between 0,5 to 2,0% (Hiddink, 1990), but many respondents reported losses of more than 5% and even as high as 7%. It must be taken into consideration that, should a reported product loss be a deliberate underestimate on the part of an individual respondent, that particular value will compare favourably with the rest of the data.

Clearly, the topic of product losses remains a sensitive one, since 39 respondents either failed or refused to state the product losses, or reported zero losses or losses below 0,5%. It is interesting to note from Fig. 2 that respondents from Group 2 reported very low and very similar product loss values. Since this group consists solely of milk powder manufacturers, these low values may be explained by the advanced technology and high automation levels involved in large-scale milk powder manufacturing.

Water management

Due to the international tendency towards increased dairy plant sizes, effluents emanating from any single large-scale operation, will show corresponding increases in volume. From Figs. 1 and 2, it is evident that many dairies can benefit from better water management and product loss control. This will result in immediate savings where effluent is discharged, at high cost, to municipal sewers. Where effluents are used to irrigate pastures or lands, improved product-loss control will lessen the negative impact on soil condition. Even though dairy-generated effluents have some value as fertilisers and also do not contain serious toxic substances, land application is objectionable as complexing agents and detergents are able to mobilise heavy metals in the soil and ground water (Hiddink, 1990).

The Presidents Council (Republic of South Africa, 1991) recently published an extensive report, with suggestions and recommendations on a national environmental management system. This environmental management system will have ecological, economic, social and legal implications. It is important to realise that the report reflects intended Government

policy regarding the management of the environment and may soon find its way to actual legislation. A significant observation made is that in many parts of South Africa the reuse of water-borne effluents will become increasingly important. It is thus important that all industrial water users, not only in the food industry, should determine the true scope of their effluent situation.

Conclusions

Environmental problems are getting more and more attention world-wide. Though the dairy industry is not known as an industry causing severe environmental problems, it should nonetheless consider its environmental impact.

This postal survey has contributed to a better understanding of the effluent production and disposal in the South African dairy industry. Compared to the NATSURV 4 survey (Water Research Commission, 1989) where the emphasis was on industrial water consumption, this postal survey with emphasis on effluent production and disposal, covers more dairies and a greater proportion of the milk volume produced in the country. In the current survey, the dairy processors had the opportunity to assess the situation in their own factories, whereas the NATSURV 4 survey was personally conducted on-site by the surveying team.

It can also be concluded that the smaller dairies are experiencing less trouble with regard to effluent disposal than the bigger milk processors and factories. The discharge of effluent to municipal sewers is expensive, especially for the larger dairies. High levies are not necessarily an indication of poor water management techniques, although it is clear that many dairies can benefit from improved water management techniques. Improving a factory's water management implies improved staff training, especially regarding attitudes towards efficient water use, water conservation and effluent treatment and management.

Considering that the respondents to this postal survey represent a significant portion of the milk processed in South Africa, it can be concluded that the dairy industry is optimistic in terms of pollution management research and training options. This optimism is also reflected by the high percentage of respondents seeking more information on the subject and that many indicated that they would welcome a seminar on effluent management and treatment. This can be seen as a positive response and the need for more information must be met.

Acknowledgements

The authors wish to express their sincere gratitude to Anne-Marie Vögel for her assistance, to the respondents for their co-operation, and to the Water Research Commission for financial support and consent to publish the data (WRC Project No. 455).

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