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EVALUATION OF WATER SOFTENING SYSTEMS FROM A COMPARATIVE PERSPECTIVE

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ABSTRACT

Water can be softened by processes based on ion-exchange and on the dosing of chemicals which are mainly lime, caustic soda and soda ash.

The techniques based on dosing of chemicals can be divided into coagulation and crystallisation processes. The choice between precipitation and crystallisation is mainly determined by factors such as cost, reliability, and operational efforts.

Crystallisation process is carried on in a pellet reactor in which $CaCO_3$ is not formed as flocs in the water, but is deposited onto a carrier material - *usually sand* - in the form of pellets. The most typical aspect of a pellet softener is a fluidised bed of grains on which crystallisation of $CaCO_3$ takes place. The grains move freely in the upward flow so that cementing of grains is prevented.

The softening of water in a pellet reactor has a number of major advantages over softening using coagulation installation. In the first place, the crystallisation of the calcium carbonate onto the sand particles is very fast which means that large volumes can be treated in a relatively compact installation. In addition to this, the process is very flexible because varying current volumes can be treated, varying between 40 and 150 m^3/m^2/hour. Another advantage is that the calcium carbonate is obtained as a water-free and granular product as a result of which sludge dewatering becomes unnecessary. Finally, since the softening reactions take place virtually completely in the reactor, the problem of post-softening scarcely arises.

In this paper, critical evaluation of water softening systems - *primarily based on the data belonging to the recent applications in Turkey* - will be presented from a comparative perspective which consists of technical, economical and environmental factors.

RESUME

L'eau peut être adoucie par des process basés sur des échanges ioniques ou sur le dosage de réactifs chimiques qui sont principalement la chaux, l'hydroxyde de sodium ou le carbonate de sodium.

Parmi les techniques qui font appel au dosage de réactifs chimiques, on distingue les procédés de coagulation et de cristallisation. Le choix entre l'une ou l'autre voie est principalement déterminé par des facteurs comme le coût, la fiabilité et la facilité de mise en ceuvre.

Le process de cristallisation a lieu dans un "pellet reactor" dans lequel le $CaCO_3$ ne précipite pas sous forme de flocs dans l'eau, mais est précipité sur un support (habituellement du sable) dans le réacteur.

L'adoucissement de l'eau dans un pellet reactor a un bon nombre d'avantages par rapport à l'adoucissement utilisant un système de coagulation-floculation. En premier lieu, la cristallisation du carbonate de calcium sur les grains de sable est très rapide, ce qui fait que d'importants volumes d'eau peuvent être traités dans une installation de petite taille. De plus, ce process, très flexible, permet également de traiter des quantités variables, de 40 à 150 m^3/m^2/heure. Un autre avantage est que le carbonate de calcium ainsi obtenu est exempt d'eau et sous forme de granulés, ce qui rend inutile toute opération de déshydratation. Enfin, puisque la réaction d'adoucissement a lieu presque complètement dans le réacteur, le problème de post- adoucissement est très fortement réduit.

Dans cette présentation, une évaluation critique des systèmes d'adoucissement d'eau (principalement basés sur des résultats de récentes applications en Turquie) consiste en une comparaison des caractéristiques techniques, économiques et environnementales des différents traitements.

KUZBERICHTE

Wasser kann chemisch enthärtet werden mit Systemen auf Basis von Ionenaustausch einerseits und einer Mischung mit Reagenzen andererseits, wie z.B. Kalk, Natronlauge und Soda.

Betrachten wir Systeme auf Basis von Einmischung von Reagenzen, dann gibt das moderne System mit Pellet – Reaktoren wichtige Vorteilen im vergleich mit dem Einsatz konventioneller Koagulations–Systemen. Zum ersten ist die kristalmässige Präzipitation von Calcium–Carbonat auf Entkenten (Sandkörnchen) sehr schnell, so dass grosse Mengen Wasser in vergleichsmässig klenen Anlagen aufbereitet werden können. Dabei ist der Prozess sehr flexibel, da es möglich ist veränderliche Mengen aufzubereiten, zum Beispiel 40–150 m^3/m^2/st in eine und diese be Anlage-Dimension. Ein anderer wichtiger Vorteil ist der Austritt des Restproduktes im Form massiver, wasserfreier Kügelchen, so dass Schlammentwässerung nicht nötig ist. Zum Schluss sei angemerkt dass die Enthärtung in Pelletreaktoren fast vollständig ablauft, so dass Nachenthärtung selten nötig ist.

In diesem Beitrag werden–hauptsächlich auf Grund von eigenen Erfahrungen in der Türkei – unterschiedliche Enthärtungssystemen miteinander verglichen hinsichtlich den Kriterien Technologie, Wirtschaftlichkeit und Umweltrelevanz.

INTRODUCTION

The consumer judges water to be hard if much soap is required to produce lather. The hardness of most waters is due the following components, which are held in solution:

1. Calcium bicarbonate (by solution of $CaCO_3$ in waters containing CO_2),
2. Magnesium bicarbonate (by solution of $MgCO_3$ in waters containing CO_2),
3. Calcium sulfate (in form of $CaSO_4.2H_2O$ – *known as gypsum*),
4. Magnesium sulfate (in form of $MgSO_4.7H_2O$ – *known as epsom salts*).

In addition to sulfate forms, chlorides and nitrates of calcium and magnesium may also be present sometimes. As long as any of these compounds or a combination of them exist, water is hard.

The softening of hard water for municipal consumption and industrial use is a well-known process, aimed at reducing the concentration of calcium and magnesium compounds in water. Water softening can be carried out centrally at water plant or at the location of use. Hard water is made soft by:

1. By an exchange process which consists of replacing the divalent calcium and magnesium ions with monovalent sodium ions.
2. a treatment which changes calcium and magnesium compounds from a soluble to an insoluble form,

While the first process is ion exchange – *zeolite or resine* – process, the second one is based on dosing of chemicals – *which are mainly lime, caustic soda and soda ash*.

Ion exchange removes unwanted ions from the raw water by transferring them to a solid material – *called ion-exchanger* – which accepts them while giving back an equivalent number of a desirable species stored on the ion-exchanger skeleton. These process have some characteristics that are less favourable due to the production of relatively high amount of salty waste water, increase in the sodium content of the water, and relatively large costs.

The techniques based on dosing of chemicals can be divided into coagulation and crystallisation processes.

The coagulation process is based upon the formation and sedimentation of $CaCO_3$ flocs in the sludge form. One primary drawback of this method is the slow rate at which the formation and sedimentation of $CaCO_3$ flocs is achieved, as a result of which a relatively large softening installation is required. In addition to this, the treated water is not stable and post-softening can occur leading to particularly troublesome lime deposits in pumps, storage chambers and pipes in the actual treatment plant itself, and also in the distribution area. Since softening sludge has a very high water content, dewatering is often required before the sludge can be disposed of.

FLUIDIZED BED WATER SOFTENING "PELLET REACTOR"

Crystallisation process is carried on in a pellet reactor in which $CaCO_3$ is not formed as flocs in the water, but is deposited onto a carrier material - *usually sand* - in the form of pellets. The most typical aspect of a pellet softener is a fluidised bed of grains on which crystallisation of $CaCO_3$ takes place. The grains move freely in the upward flow so that cementing of grains is prevented.

An efficient approach to large scale central softening of drinking waters is chemical precipitation of temporary hardness – *which consists of calcium and magnesium bicarbonate* - by means of modern pellet reactors. However, pellet reactors can be used in combination by ion-exchange (resine) systems to prepare industrial waters, as well (Figure 1).

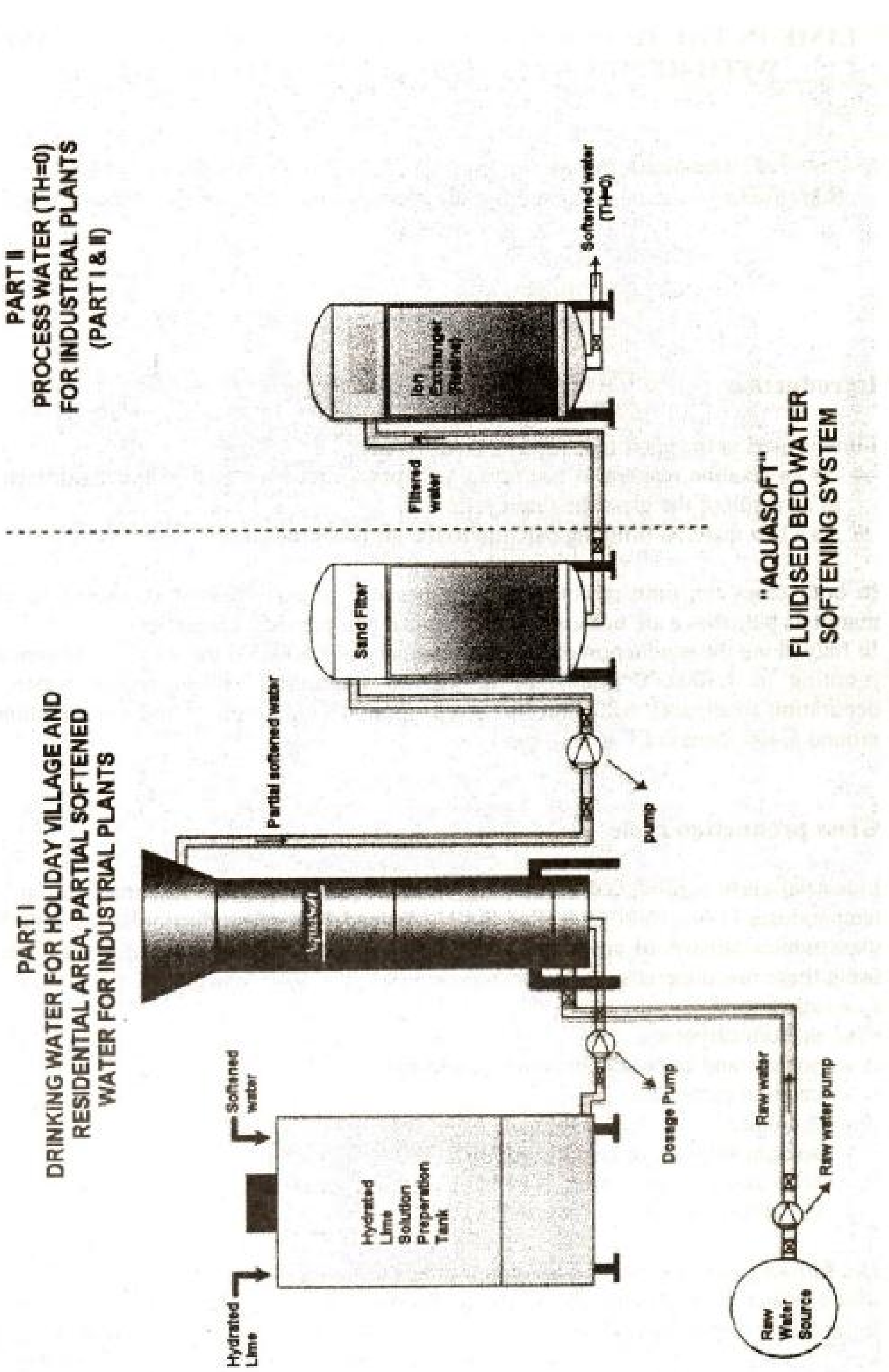
The softening of water in a pellet reactor has a number of major advantages over softening using coagulation installation. In the first place, the crystallisation of the calcium carbonate onto the sand particles is very fast, which means that large volumes can be treated in a relatively compact installation. In addition to this, the process is very flexible because varying current volumes can be treated, varying between 40 and 150 m^3/m^2/hour. Another advantage is that the calcium carbonate is obtained as a water-free and granular product as a result of which sludge dewatering becomes unnecessary. Finally, since the softening reactions take place virtually completely in the reactor, the problem of post-softening scarcely arises.

Another major advantage of the pellet reactor is cost efficiency. Table 1 presents some figures – *which are based on real data obtained from some industrial complexes located near Izmir* – to compare the costs and benefits of the "ion exchange (resine) systems" and "the combination of ion exchange (resine) + pellet reactor systems".

CONCLUSION

Pellet reactors - *which have high operational and significant cost efficiency and produce minimal volume of waste in the form of useable pellets* - is applied in several West–European countries – *particularly in the Netherlands*. In western Turkey - *due to underground waters with high temporary hardness* - there is a big potential for water softening with pellet reactors, and there are some recent applications converting this potential into a real market. Lime producers of other countries should also introduce this system to their existing costumer to be competitive against other lime-free water softening systems - *like reverse osmosis and membrane filtration*

SPECIFICATION OF INLET RAW WATER AND SYSTEM										
Raw Water Flow rate (m^3/saat)		125		250		60		52		150
Total Hardness (°F)		**17,00**		**64,00**		**43,00**		**30,86**		**28,00**
Temporary Hardness (°F)		10,00		29,00		24,00		17,40		9,00
Permenant Hardness (°F)		7,00		35,00		19,00		13,46		19,00
Residue Hardness (°F)		**9,00**		**37,90**		**23,80**		**15,20**		**20,35**
Salt Price ($/kg)		0,06		0,05		0,07		0,05		0,06
Resine Price ($/l)		4,89		4,89		4,00		4,89		1,20
Hydrated Lime Price ($/kg)		0,06		0,06		0,06		0,06		0,06
Sand Price ($/kg)		0,06		0,06		0,06		0,06		0,06
Electric Price ($/KW)		0,07		0,07		0,07		0,07		0,07
	ECONOMIC COMPARISON OF RESINE AND PELLET REACTOR SYSTEMS									
	Resine System	Resine+Pellet Reactor	Resine System	Resine+Pellet Reactor	Resine System	Resine+Pellet Reactor	Resine System	Resine+Pellet Reactor	Resine System	Resine+Pellet Reactor
Amount of resine (l/5 yıl)	5.434	2.877	40.912	24.228	6.597	3.651	4.103	2.021	10.739	7.805
Amount of salt (kg/gün)	6.521	3.452	49.094	29.074	7.916	4.381	4.924	2.425	12.887	9.366
Amount of hydrated lime (kg/saat)	-	16,65	-	96,57	-	19,18	-	12,05	-	17,98
Amount of sand (kg/saat)	-	3,33	-	19,31	-	3,84	-	2,41	-	3,60
Amount of electric (KW/gün)		408,00		408,00		89,00		62,40		200,00
Resine Cost ($/yıl)	5.314	2.814	40.012	23.695	5.278	2.921	4.013	1.977	2.577	1.873
Salt Cost ($/yıl)	142.810	75.599	895.966	530.601	202.254	111.935	89.863	44.256	282.225	205.115
Hydrated lime cost ($/yıl)	-	8.751	-	50.757	-	10.081	-	6.333	-	9.450
Sand cost ($/yıl)	-	1.750	-	10.149	-	2.018	-	1.267	-	1.892
Electric cost ($/yıl)	-	10.424	-	10.424	-	2.274	-	1.594	-	5.110
TOTAL COST ($/YIL)	**148.124**	**99.338**	**935.978**	**625.626**	**207.532**	**129.229**	**93.876**	**55.427**	**284.802**	**223.440**
BENEFIT (%)		**32,94**		**33,16**		**38,00**		**41,00**		**22,00**


PART I
DRINKING WATER FOR HOLIDAY VILLAGE AND
RESIDENTIAL AREA, PARTIAL SOFTENED
WATER FOR INDUSTRIAL PLANTS
PART II
PROCESS WATER (TH=0)
FOR INDUSTRIAL PLANTS
(PART I & II)
Hydrated Lime
Softened water
Hydrated Lime Solution Preparation Tank
Dosage Pump
Raw water
Raw water pump
Raw Water Source
Partial softened water
pump
Sand Filter
Filtered water
Ion Exchanger (Resins)
Softened water (TH=0)
"AQUASOFT"
FLUIDISED BED WATER
SOFTENING SYSTEM