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Improving water reuse in an oil refinery and avoidance of the pinch analysis trap with particular reference to the Atyrau refinery in Kazakhstan

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ABSTRACT

Due to water scarcity over the globe finding ways of re-using wastewater is becoming more and more essential so as to put less strain upon natural resources. This paper provides new insights in particular by introducing for the first time the necessity of taking a balanced approach when using pinch analysis; cooling water demand can be as important as energy demand for inland locations particularly when externalities are taken into account. This is particularly important for Kazakhstan which is a dry, inland country, where climate change is exacerbating issues around water usage. Recent sharp reductions in the flow of the Zhayik river in the Atyrau region of Kazakhstan has magnified the water shortage in the Atyrau region and forced the government to develop new water policies to address this most urgent and serious matter. This paper analysed the water consumption of the main water consumers, the Atyrau oil refinery (AR) with respect to the country's other refineries and found that there has been a significant performance gap. Recently modernisation at AR has sought to transition it from open loop wastewater treatment to closed loop wastewater treatment. Not only has this significantly reduced the water intake from the Zhayik river but there is now zero discharge to the evaporation ponds. Eliminating this discharge prevents soil and groundwater contamination. Conventional methods of wastewater treatment within the framework of modernisation project, called "Tazalyq", are able to remove the majority of contaminants. However, this is still not sufficient to deal with small stable oil droplets (<5 μm). Methods to further enhance the treatment such as membrane technology and segregation are discussed. The former can concentrate small stable droplets without further use of chemicals, and the permeate is quality water that can be recycled. Pilot plant results on the use of reverse osmosis to treat blowdown water are also included. Implementation of this process would reduce water demand by *circa* 10%. Such an addition to modernisation project would further reduce the water intake from Zhayik river.

Keywords: Water reuse; Water recycling; Pinch analysis; Water-energy nexus; Atyrau refinery; Kazakhstan

1. Background

1.1. Kazakhstan: contextual information

The Republic of Kazakhstan, the largest Central Asian country, is actively integrating itself into the world community and reforming its economy. Since 2010, the country has been pursuing an industrial policy aimed at diversifying its economy and reforming the institutional environment [1].

The Republic of Kazakhstan is an oil producing country. Its regions and the location of its major refineries are shown in Fig. 1. Kazakhstan, having significant reserves of hydrocarbon raw materials (about 3% of world reserves), is one of the 15 leading countries in the world producing this raw material along with the countries of the Middle East, Russia, Venezuela, China, Norway, Canada, Great Britain, Indonesia and Brazil. At the same time, it should be noted that the main consumers of hydrocarbons produced in

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Fig. 1. Map of Kazakhstan indicating location of its river basins and oil refineries.

Kazakhstan are the USA, Japan, China, Korea, India and European countries, which account for 60% of the world's consumption of hydrocarbon raw materials [2].

The role of water use in industry is crucial as the volume of water consumed during the industrial processes is large and it is increasing every year [3]. According to the statistics of 2018, industrial segment has used 5.536 km^3 of total water consumption (about 22.3%). At the same time, water intake from surface sources amounted to 5.22 km^3. As shown in Fig. 2 the oil industry, non-ferrous metallurgy and thermal power plants are the among the largest consumers of water [4].

The amount of water used for oil refining depends on the processes involved in the refinery. Crude oil refining processes such as fluid catalytic cracking, hydrocracking, reforming, isomerisation, vis-breaking (a mild form of thermal cracking, which lower the viscosity of vacuum residues) are typical refinery processes that produce different oil products with different levels of water consumptions. Water consumption during these processes typically vary from 0.35 barrels of water per 1 barrel of crude oil to 0.45 barrels/barrel of crude oil [5]. One of the most water consuming process at a refinery is the production of gasoline (petrol), which can consume up to 0.70 gallons of water/gallon of gasoline [6]. These statistics of water consumption oblige refineries worldwide to make water use sustainable and reusable.

Aral-Syrdarya, Balkhash-Alakol, Irtysh, Ishim, Zhayik-Caspian, Nura-Sarysu, Tobol-Torgai, and Chu-Talas-Assa are the eight water resource basins of Kazakhstan. The country's water resource potential is unevenly distributed. Due to this uneven distribution of water resources around the country it poses serious issues to the economic and social development of Kazakhstan [7]. This is especially so in the Atyrau region, where water provision is highly dependent upon the Zhayik river for all needs including household water, agricultural water and industrial water. As shown in Table 1 the resource level in the Zhayik-Caspian region is low.

1.2. Kazakhstan: governance of the water sector

Water management is an area of activity that aims to meet the needs of the population and various sectors of the economy with respect to water. It is responsible for the rational use of water resources and their protection from pollution, clogging and depletion. It operates water management systems and is also responsible for the prevention and elimination of harmful effects of wastewater. Water management in a number of countries is an independent branch of the economy, and as a branch of the national economy of the country also sets itself the implementation of tasks affecting water flora and fauna.

The main task of the water industry is to provide all sectors and types of economic activity with water in the required quantity and corresponding quality. By the nature of the use of water resources, the sectors of the national economy are divided into water consumers and water users. When water is consumed, water is withdrawn from open sources (rivers, lakes and reservoirs) and underground sources (aquifers) and is used in industry, agriculture, for household needs and other sectors of the economy. Water consumption in terms of the use of water resources is subdivided into returnable (returning to the source) and irrevocable (losses).

Since 2017, Kazakhstan has been following the strategy of Integrated Water Resources Management (IWRM) [8]. Integrated water resources management is a management system based on taking into account all types of water resources (surface, groundwater and return waters) within hydrographic boundaries, which links the interests of various sectors and levels of the hierarchy of water use, involves all stakeholders in decision-making, promotes efficient use water, land and other natural resources in the interests of sustainable provision of the requirements of nature and society in water. IWRM is based on a number of key principles: hydrographic, public participation, accounting for all types of water resources and all types of water users, consideration of environmental requirements, with a focus on water conservation, economic management and financial stability.

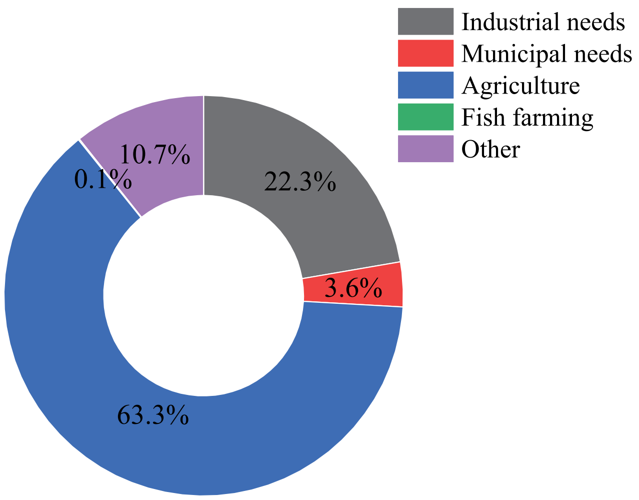

Fig. 2. Water intake in 2018 by sectors of the economy in Kazakhstan (%) [3].

The main tasks facing the water management industry of Kazakhstan are the guaranteed provision of the population with quality drinking water, creation of favourable conditions for the functioning of all sectors of the economy, protection of water resources from depletion and pollution, responsibility for their quantitative and qualitative reproduction. Despite these promising tasks indicated by legislation, omissions have been observed. A number of such observed omissions include ground pollution, irrational use of water, non-compliance with Maximum Permissible Concentration levels, irrational use of water and the high content of oil products in the water.

1.3. Atyrau region

Atyrau region is located in the Caspian lowlands below sea level. Transgressions and regressions of the Caspian Sea in ancient and modern times, the activity of rivers, the vast influence of the sea on the coastal landscape, the rise of the sea level and the associated environmental problems and the rich flora and fauna of the Caspian Sea have made this region a unique location. Its uniqueness necessitates the sustainable conservation of the region's biological diversity, genetic resources and ecosystems. The common features of the northeast coast relief are reflected in the main geotectonic element of the territory: the Caspian tectonic depression and the corresponding accumulative lowland plains. The climate here is continental, obviously dry, with hot summers and moderately cold winters. The absence of high natural barriers promotes the free penetration and movement of Atlantic moisture mass and cold Arctic air as well as the dry air of the subtropical deserts of Kazakhstan and Central Asia. Being the main area for oil production in the Republic of Kazakhstan, the Atyrau region is considered to be under great anthropogenic impact. Insufficient ecological management and oilfield accidents in the refinery plants have resulted in continuous

Table 1
Water resources of the Republic of Kazakhstan (km^3) [8]

Water management basin	Average long-term runoff			Groundwater	
	Formed outside the Republic of Kazakhstan	Formed in the Republic of Kazakh-stan	Total	Forecast resources	Explored and approved reserves
Aral-Syrdarya	18.93	3.36	22.29	9.29	1.13
Balkhash-Alakol	9.75	15.43	25.18	20.01	7.26
Ertis	4.48	25.92	30.40	9.56	2.87
Esil	0.00	2.77	2.77	2.31	0.16
Zhayik-Caspian	8.26	4.13	12.39	7.37	0.97
Nura-Sarysu	0.00	1.37	1.37	3.32	0.82
Tobol-Torgai	0.31	1.63	1.94	3.62	0.48
Shu-Talas	2.91	1.33	4.24	8.79	1.75
Total	44.64	55.94	100.58	64.27	15.44

oil leaks and heavy-metal pollution leading to soil degradation and the subsequent decrease of plant biodiversity [9]. The impact of industrial activity upon the local ecology was put into sharp focus by the massive fish die-off in the delta region of the Zhayik river just south of Atyrau in 2018 December. The precise cause is disputed but the scale created a large shock and was deemed to indicate the need for improved ecological management [10].

1.4. Atyrau oil refinery

Atyrau refinery LLP ("The Project Developer") is a subsidiary of JSC "KazMunaiGaz" (KMG) and the largest oil refinery plant in Kazakhstan with installed crude oil refining capacity of 5.5 million tons/y, producing up to 35 types of oil products, mainly motor gasoline A-80, 92, Motor Gasoline Premium 95, diesel fuel, jet fuel, domestic heating fuel, white spirit, fuel oil, vacuum gas oil, hydrocarbon gas, petroleum coke, technical gas. The Atyrau refinery was constructed and started operations in 1945. The raw material being refined is a crude oil with a high paraffin content, from Mangyshlak oil deposits of the western regions of Kazakhstan. Its initial refinery capacity, when it was commissioned in 1945, was 800,000 tons of oil per year [10]. Its substantial development has been documented by Cherdabaev [11]. A comparison with the other two refineries is given in Table 2 where it is shown that currently the water usage in the Atyrau refinery is both relatively high (in terms of water used per tonne of product) and also the highest in absolute terms. The other two refineries date from 1978 and 1985 and are located in river basins with a greater supply (Table 1 and Fig. 1).

2. Use of water in Atyrau oil refinery

The water used in an oil refinery depends on the processes operated at the refinery. The greatest area of consumption is for cooling. Significant amount of water is required to cool the temperature of process units and equipment. Additionally water is used as a cooling agent for final product [12]. Atyrau oil refinery produces over 35 petroleum products, and the technological scheme is depicted in Fig. 3 [13]. Water for Atyrau refinery is withdrawn from Zhayik river, the only surface water located in this region which originates in the Russian Federation (at which point it is called the Ural River) and discharges a short distance below Atyrau into the Caspian Sea via a fine delta.

Atyrau refinery (Fig. 3) processes the crude oil mainly coming from field "Tengiz". Tengiz crude is considered to be very sulphurous due to the amount of sulphur bearing compounds in the crude oil being up to 18%. As indicated in Table 3, this refinery is the only oil refinery in Kazakhstan that produces petrochemicals. Also, its product mix is different. For these reasons it is a heavier user of water than the other two refineries, Table 4. Indeed, only one refinery has a water usage level comparable with the 0.35–0.7 m^3 of water per m^3 of product that was indicated in section 1.1 as being typical. Interestingly that refinery is the only one where the processing of indigenous crude is very low; for Shymkent, indigenous crude is around just 3% whereas for Pavlodar it is close to 30% and for Atyrau over 50%. Nevertheless, the high levels in Table 4 suggests that there is scope to improve the level of water recycle and reuse is up to 18%. This high content of sulphur makes crude oil processing challenging as well as contaminating the wastewater with sulphurous material. Apart from this, there was another way that wastewater contamination could possibly cause human disease. This was through the contamination of wastewater with phenols, organic acids and alcohols during the complex processing of oil and gas and dehydration and desalination processes and the practice before the modernisation project of sending the wastewater containing phenols, organic acids, alcohols to evaporation pond, thereby contaminating the soil and groundwater, and affecting both flora and fauna. Implementation of the modernisation project where zero discharge is aimed for can exclude the question of environment contamination. However, water will still be discharged to the municipal wastewater treatment plant.

2.1. Wastewater treatment technology in Atyrau oil refinery

The wastewater treatment plant is located onsite at the Atyrau refinery. Figs. 4 and 5 are schematic flowsheets of the Atyrau refinery wastewater treatment plant prior to and subsequent to the modernisation project "Tazalyq" that is mentioned in the next section. The wastewater treatment plant consists of mechanical and biological wastewater treatment facilities. Mechanical treatment facilities unit with a capacity of 12.0 thousand m^3/d, started operating in 1973. The feed is industrial effluents from technological installations containing water effluents, oil and oil products, mechanical impurities, as well as industrial and storm effluents from plant sites and domestic household

Table 2
Major refineries hydrocarbon refining volumes in Kazakhstan, 2021

Refinery	Hydrocarbon refining volumes, thousand tonnes	River basin in region	Water intake[a] m^3/tonnes	Available water resources	River
Atyrau	5,473	Zhayik-Caspian	1.33 (2021)	Surface water only	Zhayik
Shymkent	5,164[b]	Aral-Syrdarya	1.08 (2019)	River, rainfall	Badam
Pavlodar	5,407	Ertis	0.30 (2020)	River, rainfall	Ertis

Sources of data: KazMunayGaz Annual Report 2021: ar_en_annual-report_spreads_kmg_2021.pdf;
[1]Latest available data. Table 4 for further information;
[2]Net to KMG 2,582; refinery has CNPC as a co-owner.

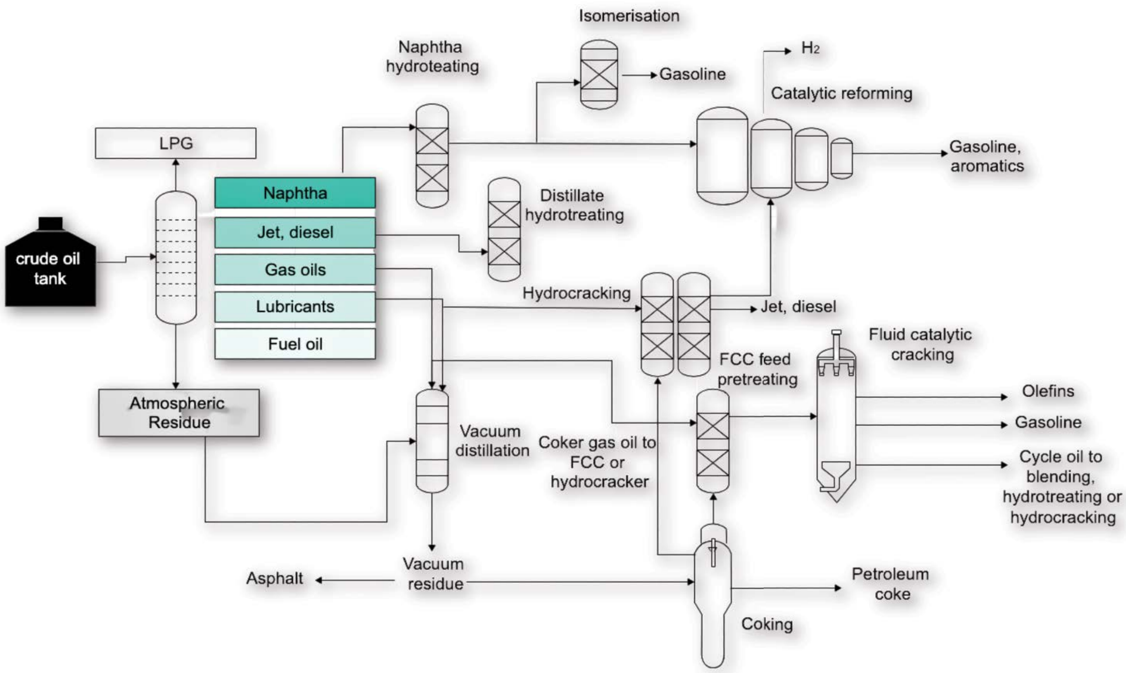

Fig. 3. Atyrau oil refinery plant.

Table 3
Kazakhstan refineries: oil product output in thousand tonnes for 2021

Oil products	Atyrau refinery	Pavlodar refinery	Shymkent refinery
Light	3,169 (65%)	3,736 (76%)	4,080 (87%)
Dark	1,499 (31%)	862 (18%)	616 (13%)
Petrochemicals	52 (1%)	0	0
Other	147 (3%)	337 (7%)	8
Total	4,867	4,935	4,704

Sources of data: JSC NC KazMunayGaz Annual Report 2021: [KMG e-source].

Table 4
Water usage data for Kazakhstan's refineries (m^3 of water per m^3 of product)

Refinery	Year 1	Year 2	Year 3	Period of data availability
Atyrau	1.32	1.37	1.33	2019–2021
Shymkent	0.64	1.06	1.08	2017–2019
Pavlodar	0.34	0.31	0.3	2018–2020

Sources of data: (1) Atyrau refinery [E-source]; (2) Pavlodar refinery [E-source]; (3) Shymkent refinery [E-source].

effluents. The treatment facilities consist of receiving chambers, an emergency pit, a sand trap, a four-section oil separator, an additional settling pond, a flotation plant and pumping stations. Industrial effluents, industrial storm water, and a general mixture that can be sulphurous and/or alkaline enter the industrial effluent receiving tank via the storm drain tank. The design of the storm drain allows a certain amount of wastewater to pass through it, in case of excessive flow in which case the wastewater is redirected to an emergency barn. Further, industrial effluents are pumped to a sand trap. Sand traps are used to capture the bulk of coarse mechanical impurities of mineral origin, coming with wastewater to treatment facilities. After being freed from coarse mechanical impurities, the effluents enter the receiving (distribution) chambers designed to evenly distribute the total flow from the sand traps to the oil separator chambers. The four-section oil separator and the additional settling tank are designed to capture light oil compounds. Also, at the final stage of mechanical treatment, wastewater undergoes flotation treatment. For better separation of oil products from water, separated water a NALCO 71305 flocculant is added to the floatators. Captured oil products fall into oil-gathering trays, from which they enter the captured oil collection tank, then they are pumped into the trap oil collection tanks with a volume of 1,000 m^3, after which the collected oil product is additionally cleaned, then sent for reprocessing. Purified water is pumped out to biological treatment facilities [14].

2.2. Modernisation of wastewater treatment facilities "Tazalyq"

Modernisation project "Tazalyq" enables less water intake from Zhayik river and remediation of the land that had previously been used for evaporation ponds. Whilst this greatly enhances the environment and eliminates the major source of ground and water contamination, there is still a huge concern regarding the water reuse and water treatment. Atyrau refinery aim to reuse only 15% of treated water for water recirculation system within the refinery

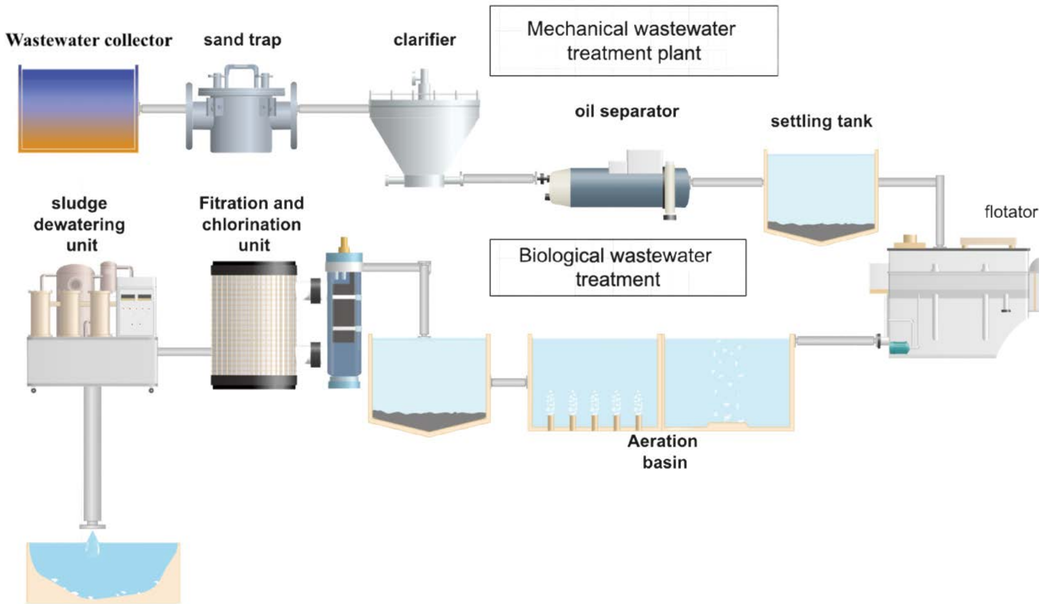

Fig. 4. Atyrau refinery wastewater treatment plant. Discharge is to the evaporation ponds (not shown).

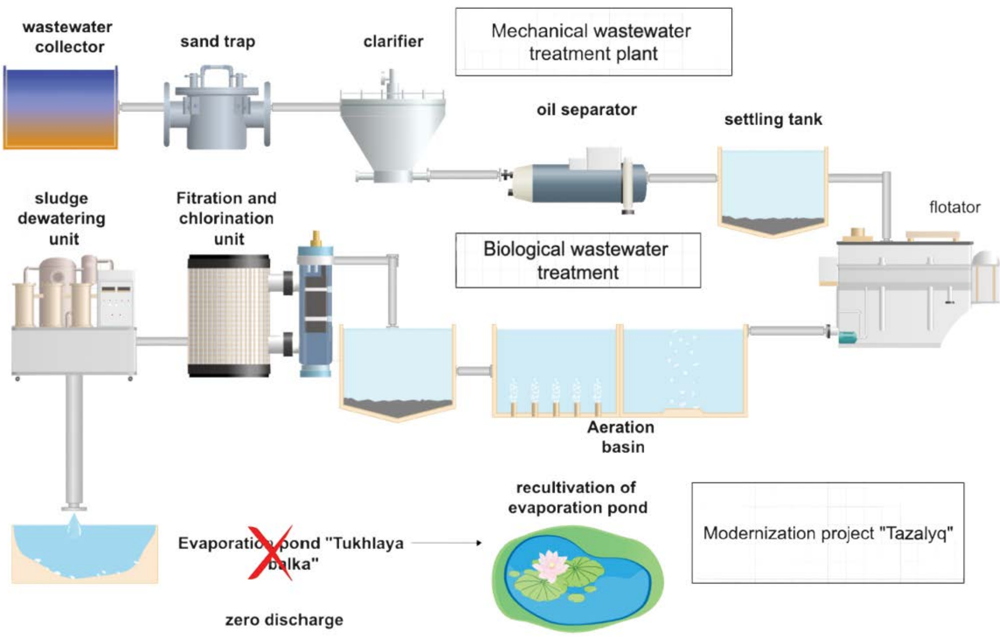

Fig. 5. Atyrau refinery wastewater treatment plant under modernisation project "Tazalyq".

and the rest is planned to be transferred to the municipal wastewater plant via new effluent pipeline for further treatment. Municipal waste in Atyrau is treated by conventional methods which purifies the water from larger particles and effluent, allowing smaller particles to remain in the content of water. Drinking water in Atyrau already exceeds the maximum allowable concentrations according to such standards as organic/inorganic compounds that contribute to many diseases. Tap water has not been used as quality drinking water for a long time. Understanding and realizing the dangers of water, people reluctantly use water for washing, bathing and other necessities.

There is a tendency in Atyrau to order bottled water or people simply install additional water filters such as Aquaphor.

2.3. Pinch analysis and its limitations

The development of the Atyrau refinery over the last few decades has probably involved pinch analysis which is a methodology developed in the 1970's and is used to minimize energy consumption in the process industries [15]. Furthermore, a key performance indicator of any oil refinery has been the percentage of a barrel that is converted into products with the aim of minimising the percentage of the original barrel that is used to run the refinery. Using pinch analysis to minimise energy supports the aforementioned KPI. However pinch analysis identifies not only hot utility demand but also the cold utility demand. Normally the meeting of latter is downplayed as seawater cooling or river water cooling is taken for granted. In an inland location in particular this ignores externalities such as environmental costs.

"Sticking to your numbers too long" is one of the five traps of performance measurement that have been identified [16]. One needs to be precise about what needs assessment and where a consequence of an industrial activity is not reflected in costs or market prices metrics are unlikely to assess the externalities. "Measuring against yourself" is one of the other traps mentioned [16] and whilst the Atyrau refinery has undoubtedly decreased its environmental footprint the improvements are unlikely to be deemed sufficient until local people have confidence to drink their tap water.

3. Additional measures to further improve water reuse and reduce water intake

Pinch analysis enabled many chemical companies around the time of the oil price shock of the 1970's and 1980's to reduce their energy consumption per unit of product. Externalities were ignored. Today there is a much greater awareness of some externalities and is wrong to use pinch analysis simply as a means to reduce the hot utility burden, which we call the pinch analysis trap. The methodology enables one to evaluate the cold utility burden (which is generally met by cooling water abstracted from rivers) and this measure needs to be integrated with the environmental costs of water supply and wastewater treatment. It is therefore crucial to use a balanced approach that addresses the full costs associated with the cooling water demand (cold utility) as well as the costs associated with the energy demand of the hot utilities. For dry, inland countries such as Kazakhstan where cooling water supply needs to be conserved, the environmental costs associated with excessive usage are high and additionally such usage places a burden on future generations. Full economic costing must involve all externalities.

Additionally, the Zhayik river begins in the Russian Federation and the possibility of transboundary river issues suggests that a precautionary approach to consumption is required. It is anticipated that segregation of water in a refinery into that which is used simply for cooling and that which is directly involved in the refinery's chemical processes will, if the full costs of treatment are assigned to the various streams, result in reduced usage.

Now some of the streams contain oil-in-water emulsions and the equipment referred to in section 2.1 will not be capable of removing the very small drops of oil. Now one of the most effective methods of concentrating oil emulsions and separating out the majority of the water is ultrafiltration and microfiltration performed with hydrophilic polymeric membranes. Several studies on the concentration of waste-based emulsions have been undertaken from as early the 1980's [17,18]. Related work on the modelling of flux decline began in the 1990's [19,20] and an improved general method of analysis has been recently developed [21]. Very recently with due recognition of the complexity of oil-in-water emulsions, a model specifically for such emulsions has recently been proposed. In this model the degree of pore blocking is determined by the membrane contact angle and the resulting surface coverage, whilst the "cake" layer is described by a mass balance and a cake erosion flux [22]. An ideal membrane system would have high water flux, zero oil permeation, steady performance and a long membrane lifespan. The progress made towards this ideal has been presented in a recent review [23].

Besides membrane processes there are other technologies including innovative wastewater treatment technology discussed within a Kazak context and described elsewhere [24]. The study indicates that within the textile facility studied up to 95% of all wastewater can be reused.

4. Discussion and future prospects

The "Tazalyq" modernisation project at the Atyrau refinery will involve the construction of a new effluent pipeline extending from the refinery for 3.5 km to a municipal wastewater treatment plant thereby replacing an existing open wastewater discharge channel and a start made to the reclamation of the current evaporation fields that extend over 860 ha. Additionally, with the upgrade of the biological wastewater treatment facilities and upon completion of the modernisation of mechanical treatment facilities, it is intended that around 15% of the wastewater sent to the municipal WWTP will be returned back to the refinery.

Internal recycle is also important and a recent study at the Atyrau refinery on the purification of blowdown water by reverse osmosis has proven, over a two-month period, to be a technological success. The pilot reverse osmosis (RO) plant had a product capacity of 0.6 m^3/h and operated at working pressure 6.5–7.0 bar (depending on solution temperature) [25]. The total salt content in the source water was 1,637 mg/L and RO unit yielded a permeate with a salt content of 8.9 mg/L. This quality reaches the standard required for boiler make-up water. It is estimated that the full implementation of this scheme could reduce the water intake to the refinery by 10% [25].

The finance for the "Tazalyq" project, at least in part, will come from the European Bank for Reconstruction and Development (EBRD) which is providing a $80 million-equivalent loan to help Kazakhstan with the upgrade of its wastewater treatment facilities at the Atyrau oil refinery [26]. The bank noted that nearly 300,000 inhabitants of Atyrau will enjoy major environmental benefits. It was noted that the remediation work is the result of a long-term engagement between the EBRD and the refinery that aims to reduce the environmental impact of the plant's operations. The increase in water reuse and the consequential reduction in the withdrawal of freshwater from the Zhayik river is especially important because as noted above the Atyrau region is well known for its low levels of rainfall. Whether progress towards full substitution of freshwater intake from the river is maintained or not will depend upon both ambition and future financing. There is an opportunity for advanced technologically ambitious sub-projects akin to the NEWater Projects of Singapore. The parallel would be two-fold. There is an opportunity to be a global leader in meeting environmental standards and the technology would need to have membranes as a vital component. The latter would not just be for oily-water separation but also for advanced wastewater treatment, that is, membrane bioreactors (MBR). As mentioned elsewhere [23], in this area membrane processes complement rather than replace conventional technology; the integration of each harnesses their respective advantages and helps to circumvent their respective shortcomings. Together higher quality product water can be achieved sustainably.

Future prospects will not only be industry specific but also dependent upon location. Geography dictates not only distance to the ocean but also the climate. The latter determines the temperature of operation within processes such as MBRs. Unlike Singapore, the variation in ambient temperature will be a factor. The effect of low temperature has been shown to affect the sustainable fluxes of a MBR in a pilot-plant located in a northern region of China with a similar climate to Kazakhstan [27]. Therefore, in developing advanced processes, studies across the whole year will be important.

5. Concluding remarks

Pinch analysis identifies not only hot utility demand but also the cold utility demand and the usefulness of the latter metric has generally been ignored in a world focused upon energy consumption per unit of product. As society becomes more aware of externalities, it is important to ascertain the ultimate cost to society of providing cooling water. This is particularly important for dry, inland countries such as Kazakhstan which are unable to site their refineries on the coast. Wastewater reuse might entail higher energy costs than continued exploitation of the natural environment but developments in this area are overdue. Recognising the importance of water consumption in the context of producing energy products can also be considered to be an important aspect of the water-energy nexus. In today's world it is no longer presumed that water supply is not linked to energy security, nor energy, particularly electricity supply, to water security [28].

In discussing performance assessment, Likierman [16] concluded that "A really good assessment system must bring finance and line managers into some kind of meaningful dialogue that allows the company to benefit from both the relative independence of the former and the expertise of the latter. This sounds straightforward enough, but as anyone who's ever worked in a real business knows, actually doing it is a rather tall order. Then again, who says the CEO's job is supposed to be easy?" To achieve complete substitution of freshwater intake from the river at the Atyrau oil refinery will surely involve a similar dialogue. Besides the technology there needs to be vision and finance. The former will involve better use of water within the refinery (perhaps using pinch analysis to focus upon the cold utility), segregation of the various water streams and further upgrade of the water recycle system. As Singapore has demonstrated at city scale that used water can be safely treated to become NEWater, Kazakhstan, and in particular its Atyrau region, have the opportunity with EBRD backing, to build upon the "Tazalyq" modernisation project, and set new standards for inland refineries, including inland refineries challenged by a continental climate. To do so, like Singapore, the various projects will undoubtedly be incorporating membrane processes such as reverse osmosis and microfiltration. Modernisation has sought to transition the Atyrau oil refinery from open loop wastewater treatment to closed loop wastewater treatment but there is also a need to implement water recycle and reuse so that the water consumption levels are more in-line with international norms. In stating this it is noted that a recent annual report of "KazMunayGas" indicated a commitment to water conservation and sustainable water use which would involve both projects aimed at reducing discharges and projects aimed at reducing water withdrawal from natural sources [29].

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