

Corrosion, Equity, Diversity, Environment, and Society – Part 1: Kashagan Pipeline Corrosion Economic and Environmental Assessment

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1 Case recall

The Kashagan Project, which is located at the North Caspian Sea, is one of Kazakhstan's signature oil development projects. Environmental and technical difficulties such as harsh winter conditions and exceptionally high H_2S partial pressure, respectively, made the Kashagan project one of the most technically challenging oilfields in the world [1]. The big oil companies and the "oil-hungry" Kazakhstan government believed tremendous wealth could be created from the North Caspian Sea hydrocarbon reservoir, creating the Kashagan oil bubble together. Unfortunately, the Kashagan pipeline leaked "acutely" in 2013 and has been leaking "chronically" since 2013 [2–5]. It is suspected that the root cause for the Kashagan pipeline leaking is sulfide stress cracking. It seems like corrosion issues, which were not appropriately addressed during the Kashagan oil field construction, were also not managed and controlled effectively during oil production. The astronomical budget blowing out and environmental disaster came proper before the dream of becoming the new Kuwait on the Caspian shore came true [6]. This report will focus on the pipeline leaking cost analysis and social-environmental impact assessment.

2 Cost Analysis

It is well known that the harsh winter conditions combined with the presence of high-pressure hydrogen-sulfide-containing gas makes the Kashagan project one of the world's most technically challenging oil and gas projects, also making Kashagan the most expensive energy project in the world [1, 7]. However, the Kashagan Consortium office website does not release project expenses. It is good to be aware that different cost analyses estimate the actual cost differently.

2.1 Construction and Pipeline Repair Cost

Corrosion issues, which imposed a severe challenge for the Kashagan oil field operation, also increased the project cost significantly [8]. In 2012, CNN Money ranked the Kashagan the world's most expensive energy project at \$116 billion of investment

[7]. The Kashagan phase one alone costs \$46.3 billion, as of March 2012 [7]. The Kashagan hydrocarbon reservoir is highly concentrated in H_2S as well as contains high pressure. H_2S is lethal at low concentrations and highly corrosive if mixed with CO_2 or salty water [9]. The hardware and pipeline used in the Kashagan project have to maintain good structural integrity as well as contain toxic gas seamlessly under the corrosive environment. Such specialized anti-corrosion equipment increases the cost and technical difficulty of the Kashagan project [8]. The sulfur content inside the hydrogen sulfide-containing gas should be flushed out and collected properly, creating the "sweeten" gas. The sulfur processing step would further increase the production and maintenance costs and complexity [8].

Under the North Caspian Sea Production Sharing Agreement, Agip started the Kashagan field construction in 2005, promising to start oil production in 2008. In 2007, after encountering the technical and logistics difficulties associated with corrosion, gas "sweetening", and the harsh winter, Agip could not deliver its promise on time [6, 8]. The parent company Eni, asked to postpone the oil production in 2010 and increased the project cost from US\$57 billion to US\$136 billion, which was doubling the original cost [6, 8]. The Kazakhstan government refused to accept the higher cost raised by Eni, suspending the Kashagan project for three months for environmental regulation violations and threatening to repeal Eni's operation license [8]. After a series of bitter negotiations and difficult discussions, a new agreement was signed in October 2008, securing Kazakhstan's future oil profit and laying down heavy penalties for delaying the start of oil production [6, 8]. Due to the 2008 contract amendments, the Kazakhstan government would no longer cover the construction and repair costs after October 1, 2013, unless the oil production started by the same date. The lead Kashagan operator, Agip, started a "deadly rush", adopting the fast-track methods and violating safety standards [6]. In November 2012, at the onshore gas processing plant, Bolashak, a pressure test was conducted at half of the actual production capacity. A valve of a hydrogen sulfide-containing tank was blown off. Fortunately, water was used in the 2012 pressure test. If hydrogen sulfide were used, all the on-site plant workers would have died. Because of Agip's fast-track construction method, the oil production readiness accelerated rapidly. In September 2013, the actual oil production began. After two acute and severe pipeline leaking incidents in 2013, the entire operation was shut down to replace its entire 200 km pipeline [10]. The pipeline replacement cost for the "recovery operation" alone was estimated at between US \$3.6 billion to US \$4 billion [10, 11]. The replacement cost for the pipeline above water is US\$ 1 million per 1 km. The replacement cost for the pipeline on the seabed is at least US\$1.5 million per 1 km. The revenue loss due to the downtime idling is around millions of dollars each day [12]. The profitability of this offshore Kashagan oil field has been constantly calculated and updated. The consortium membership has changed six times. Prior to the 2013 pipeline leaking accidents, Kazakhstancaspiyshelf, Equinor, BP, and BG had already left the Kashagan project [6]. In 2013, ConocoPhillips, a major Kashagan oil project investor from the United States, withdrew its shares in 2013 [6, 12].

2.2 Environmental Fines

In 2013, the Kashagan facilities suffered from pipeline line leaks. More than 2.8 million cubic meters of gas was flared [6]. The Kashagan Consortium was charged

with a heavy environmental fine (around US\$730 million) [6]. In 2014, the updated Kashagan agreement was signed between major oil companies and the Kazakhstan government, the agreement specified that the Republic of Kazakhstan and the state-owned KazMunayGas would not be paying for additional costs from the Kashagan development. The consortium had to pay US\$ 30 million to Kazakhstan because of the profit loss during the "recovery operation" [6]. The consortium was held accountable for the environmental damage during and after the 2013 pipeline leaking. More than 2.8 million cubic meters of gas were flared during and after the 2013 pipeline leaking incident [6]. The total environmental fine settled around US \$55 billion after the consortium promised to finance the social projects in Atyrau and Mangystau region [6].

In March 2023, the Kazakhstan government filed another environmental fine against the Kashagan oil venture for about US\$5.14 billion [5]. The Kazakhstan Ecology and Natural Resources Ministry accused the North Caspian Operating Company (NCOC) of releasing more than double the amount of sulfur permitted on the offshore oil field [5].

2.3 Benefits or Potential Benefits from Oil Production

In 2013, it was estimated that at peak production, the Kashagan field could generate \$60 billion worth of oil per year for the project investors [12]. However, it seems like the oil bubble in Kashagan was highly inflated by the beautiful oil revenue numbers [6]. Simply by developing the Kashagan oil field and entitling to the future oil production profit, most oil companies in the consortium were able to earn good money even without producing a single drop of oil. The Kashagan oil reserves were considered a high-value asset to the oil companies [6]. A lot of money was generated from the stock and oil future contracts because the oil companies were entitled to Kashagan oil "asset". Hedge funds and investment banks, which invested in oil companies based on the total assets, played a critical role in encouraging oil companies to claim more oil reserves [6]. Thanks to the opportunity of developing Kashagan oil field, the Italian company, Eni, became one of the major global oil companies [6]. This capitalization in the stock and future market helped the oil companies to earn profit despite of the pipeline leaks and continuously postponed oil production.

The situation was very desperate and gloomy for the Kazakhstan government. The National Company KazMunayGas (KMG) became deeply entrenched in debt. The total KMG's debt reached US\$10.3 billion in 2015 [6]. KazMunayGas Management claimed that the Kashagan oil can only be profitable if the oil price reaches \$100 per barrel [6]. Goldman Sachs calculated that the profitable oil price for the Kashagan oil is between US\$120 to US\$130 per barrel [6].

3 Environmental Impact Assessment

3.1 Past Environmental Protection Attempt

In August 2006, all five Caspian littoral states, Kazakhstan, Russia, Azerbaijan, Iran, and Turkmenistan, signed the Framework Convention for the Protection of the Marine Environment of the Caspian Sea [13]. The convention emphasized the importance of restoring and conserving the marine environment, protecting it from pollution [13].

The sustainable way of harvesting biological resources was also brought up in the convention [13]. However, the logistics of how to enforce the environmental regulations among all five states was not finalized [13].

Despite signing the Framework Convention for the Protection of the Marine Environment of the Caspian Sea in 2006, each littoral is responsible and only responsible for the environmental protection over their side of the water body, and no effective persecution is enforced after a major oil spill, and pollution occurs in the disputed water [14, 15]. Both Kazakhstan and Azerbaijan have abandoned oil wells in the Caspian Sea. These oil wells are submerged in the water, not only polluting the water but also eradicating fish and other marine life [14]. By estimate, 1 L of oil destroys oxygen in 40,000 L of seawater, and 1 ton of oil is capable of polluting 12 km^2 of the sea surface [16]. It is estimated that 600,000 hectares of land from Kazakhstan's Atyrau and Mangistau, cities near the Caspian Sea, are polluted, becoming less arable [14].

3.2 Natural Ecosystem Damages

In 2006, it was estimated that 15-20 million tonnes of carbon dioxide was emitted due to on and off-shore hydrocarbon production [14]. After the 2013 gas leak accident, dead birds and fish can be seen in the Kashagan area [16]. Ecologists estimated that one accidental oil spill in the Northern Caspian Sea would kill 50% of sprat, which is the main food source of sturgeons [16]. Only in July 2014, the Oil and Gas Minister of Kazakhstan realized the need to replace all pipeline networks in the Kashagan field [16]. Unfortunately, even after the pipeline network replacement, toxic and corrosive gas leaks still happen over and over in the Kashagan oil field [2-4, 12, 17]. What is more unfortunate is that all the information related to gas-leaking accidents is kept away from the public [16].

The caviar harvested from the Beluga sturgeon in the Caspian Sea is highly prized worldwide [8]. 80-90% of the world's caviar is sourced from the Caspian Sea. Unfortunately, the number of Beluga sturgeon has kept dropping, becoming an endangered species in the past few decades. Since the beginning of the Kashagan's oil field construction, the marine fauna has suffered from accidents related to oil field development and pipeline leaking every year [6]. In 2002, a survey discovered the sturgeon in the Caspian Sea are disappearing and becoming extinct. In the spring of 2000, the drilling at East Kashagan resulted in a significant amount of Caspian Seal death [8]. The most conservative calculation of the Caspian Seal death was more than 10 thousand. In 2002, a huge number of Caspian herring and sprat were dead. In the spring of 2006, 2,207 sturgeons and 337 Caspian seals were found dead. In 2009, hundreds of seals were discovered dead on the Caspian shore [6]. According to the UN's Caucasus Environment Outlook, oil pollution is the primary culprit causing the sturgeon population drop [15].

Having more profitable and larger hydrocarbon fields elsewhere and having a more diverse economy shaped both Iran's and Russia's economic interests, resulting in both countries concentrating on economic activities such as fishing and agriculture in the Caspian Sea region [14]. However, because there is no unified or international environmental regulatory committee/forums over the Caspian Sea, Russia and Iran's fishing and agricultural sectors suffered significantly from the oil and gas production in other littoral countries [14]. In 1993, the total sturgeon and caviar harvested were 1710 and

106 tons, respectively [14]. In 2009, the fishery yield dropped 90%. Only 178.41 and less than 10 tons of sturgeon and caviar were harvested in 2009 [14]. This oil and gas pollution leads to an ironic situation. Russia, which is the largest polluter in the Caspian Sea, releases more than 13 billion cubic meters of wastewater into the Caspian Sea every year. At the same time, Russia is more willing to impose multilateral environmental regulations in the Caspian Sea to protect its fishery and agriculture sector from other oil and gas polluters [14].

4 Conclusion

The "big oil" promise has been a major drive to Kazakhstan officials in investing and developing the Kashagan oil field. The success of overcoming technical and logistical difficulties requires both a healthy business model and a responsible government. A healthy business model would help oil companies benefit from producing oil efficiently and effectively. The corrosion control during the construction phase and corrosion management during the production phase would be addressed by the oil companies because any pipeline leaking and oil production postpones would hurt and diminish both the companies' total assets and oil revenue. A responsible government is needed to enforce environmental regulations, holding the oil companies accountable for social-environmental damages. Such a government would take a strong stand in asserting necessary consequences for the pipeline-leaking aftermath caused by corrosion. Unfortunately, the Kashagan field development gives a strong taste of irresponsible colonialism more than healthy-regulated capitalism. The big oil companies and a few elite local officials profited heavily from the Kashagan project, leaving the nation in debt, the region polluted, and the ecosystem damaged. The corrosion issue, which was difficult to tackle as the former Soviets had predicted in the first place, was not appropriately addressed by the colonialism-tailored oil production, resulting in astronomical budget blow-out and environmental disaster in the North Caspian Sea region. Unfortunately, limited information on the pipeline leaking accidents regarding the project cost, social impact, and environmental impact was released to the public. The purpose of the review is to draw attention to the Kashagan pipeline leaking accidents, the factors that influence corrosion management for oil production, and the consequences of not adopting proper corrosion control.

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