In-situ refinery and storage terminal environmental remediation

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In the 1960's there were five refineries built close to Ingolstadt. The location was central to the major refined products markets in Bavaria. The TAL crude oil pipeline brought the required feedstocks through the Alps from Trieste on the Adriatic. Crudes from north Africa, Russia, Black Sea ports and further afield were processed to create petrol, diesel aviation fuels and bitumen.

After more than 40 years of operation, the activities at one of those refineries were consolidated into two of the others and it closed. That is when Audi had an opportunity to invest in this site with the intent to transform it into a technology park, called IN-Campus. But first, the legacy refinery site needed to be fully remediated with a mix of appropriate environmental management technologies.

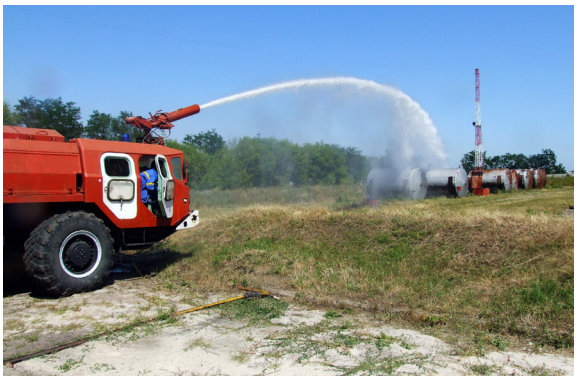
In 2017 the consortium consisting of the companies ZÜBLIN Umwelttechnik GmbH, STRABAG Umwelttechnik GmbH, Geiger Umweltsanierung GmbH Co KG and Wilhelm Geiger GmbH was awarded the contract for the site remediation and preparation for construction. The consortium has been responsible for selection of suitable measures, planning, operation and for obtaining the necessary regulatory approvals.

Copyright Bayernoil Raffineriegesellschaft mbH, Ingolstadt is the centre of refining in Bavaria, exploiting the TAL crude oil pipeline

Copyright Bayernoil Raffineriegesellschaft mbH, the refinery as it was in operation in the 1970s

Copyright AUDI AG, 75 Ha legacy refinery site on the banks of the Danube River in Bavaria

Firefighting exercises on a refinery tank farm



Firefighting exercises on refineries sometimes used PFC foams

pleted using equipment that will remain on the site until the clean-up work is complete.

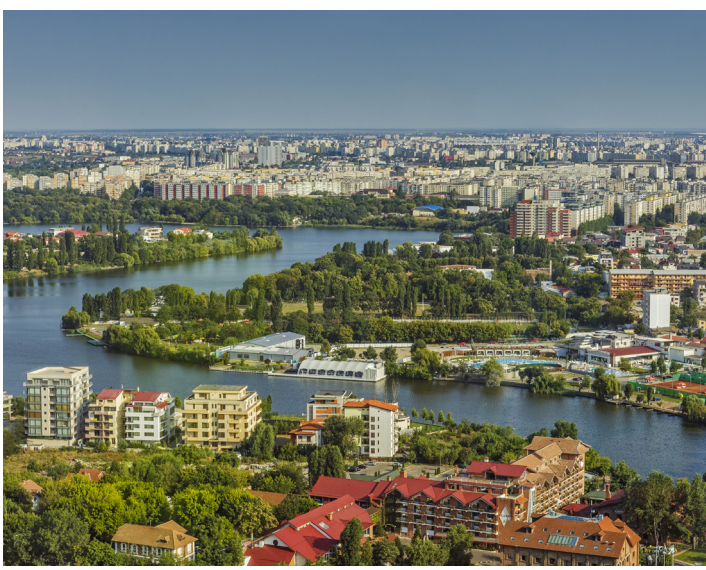
In Bavaria, where the site is located, PFC contamination is taken extremely seriously. During refinery operations, fire fighters practiced using foams, which contained PFCs. These contaminated the soil and groundwater close to the firefighting exercise area. The 'Guidelines for assessment of PFC contaminants in water and soil' requires on site treatment of PFC contaminated materials. This guideline is the strictest in Germany and could potentially become a Germany-wide or European guideline and may also be written into national or European law at some point. Therefore, this remediation project in Bavaria may serve as an example that future ex-refinery clean-up operations may be able to learn from in the future.

Bernhard Volz, Senior Engineer at Züblin Umwelttechnik GmbH manages the remediation project for the consortium. He explains, that: "every site has different soil, pollution and target environmental conditions. The technology needs to be selected and the process units must be sized and adapted accordingly".

Most of the large-scale remediation projects that we have undertaken have returned landfill sites to high environmental standards. Also, we previously cleaned up a former refinery site in Mexico. In Romania we remediated a whole OMV tank farm which has been developed to become the Petrom City in Bucharest".

The refined products storage terminal in Bucharest was a 20 Ha site on the banks of the Dâmboviţa river. It was heavily bombed in 1944

The new Petrom Headquarters building in Bucharest, location of the former OMW refined products sotrage terminal



Bucharest, on the Dâmbovița river

Mexico city skyline

during the second world war by US and German bombers. The bombing raids damaged several tanks and resulted in severe contamination of the soil and groundwater on the site. When the site came to be remediated in 2009, the main contaminants were petroleum hydrocarbons (TPH), poly aromatic hydrocarbons (PAH) and volatile BTEX group chemicals. More than 2.000 Tonnes of oil phase was extracted from the groundwater surface and handed over to Petrom´s refinery for recycling.

In Mexico City, Züblin worked alongside several partners to decontaminate the abandoned Pemex Azcapotzalco refinery. The site was subsequently turned into 'Parque Bicentenario', an urban oasis which now attracts more than a million visitors each year. For more than fifty years the refinery had released lead, benzene and heavy metals into the air, contributing to the city's reputation as one of the most polluted cities worldwide at that time.

The soil at the old Pemex refinery was saturated with pollutants such as MTBE and chemicals in the BTEX group. Pollution was at an average depth of 3.5 metres but reached a depth of 9m in some locations, resulting in the need to excavate and remediate 1.1 million cubic meters of soil. The groundwater was also heavily contaminated, and a 1,100 m long permanent barrier was sunk into the ground to a depth of 2.5m to ensure that groundwater does not flow to Mexico City's water distribution system.

Volz continues to say that "our previous downstream energy sector site remediation experience has ensured that we could design and implement suitable processes for the refinery remediation project at Ingolstadt". He continues to say that "at Ingolstadt the main pollutants are heavy oils, lighter fuels and PFCs. Much of the soil is a mixture of gravel and sand. This means that it is highly permeable, and the remediation project is using a combination of technologies which are suited to the local conditions to return the site to an acceptable state for future use as a technology park".

Air sparging is used to release volatile pollutants from 10 hectares of land where the refinery and its associated storage tanks once stood. These chemicals are then either incinerated using a flare or catalytically oxidised.

To remediate the groundwater, several boreholes have been drilled at the downstream part

Copyright ZÜBLIN Umwettechnik GmbH, Air sparging equipment is used to release lighter hydrocarbons for incineration or catalytic destruction

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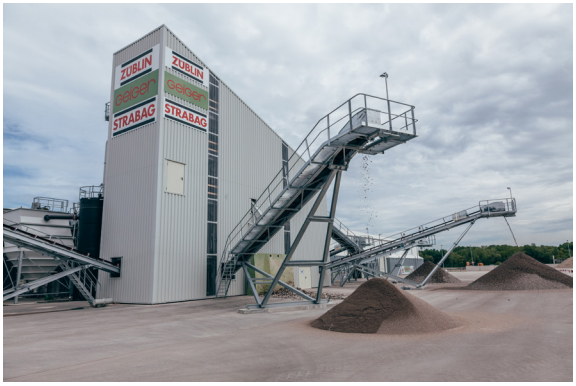
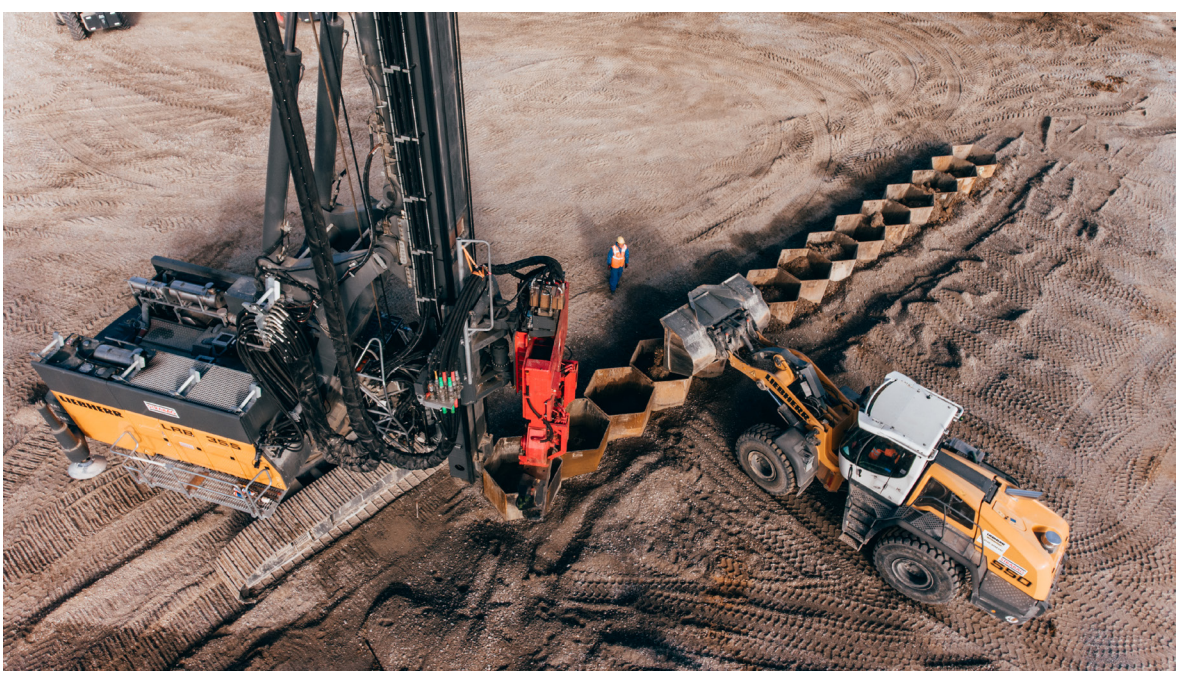


Copyright ZÜBLIN Umwettechnik GmbH, In-situ soil washing and grading process unit

of the site to intercept the groundwater before it flows to the Danube River catchment area. From these wells, the groundwater is pumped to the surface where it is purified using a water treatment system which relies on a combination of aeration, precipitation of iron, flocculation, sedimentation, sand filtration and activated carbon adsorption processes. Amongst other things, the process is designed to remove iron-salts and highly mobile PFC chemicals from the groundwater.

1,200 Tonnes per day of contaminated soil from the ground are excavated and thoroughly washed on site in a purpose-built unit constructed and operated by the consortium which is responsible for the site remediation operations. After this washing process, 90% of the excavated gravel and sand can be returned to the site to form a clean and stable foundation for future building construction. A minimal amount of the sludge results from the washing process. This material is compressed to a cake containing most of the hydrocarbon pollutants from the legacy refining operations. It is taken offsite for incineration or landfill.

The soil excavation is undertaken using a variety of techniques. In places, the excavation depth is 10 metres. To stabilise the ground for removal



Copyright ZÜBLIN Umwettechnik GmbH, Pile driving machine to enable deep soil excavation for washing

of the contaminated soil and replacement with washed soil, a honeycomb grid is created using hexagonal pipes. A purpose-built pile vibrator can sink the pipes in minutes to accelerate the remediation process and soil excavation can then be carried out independent from groundwater influence.

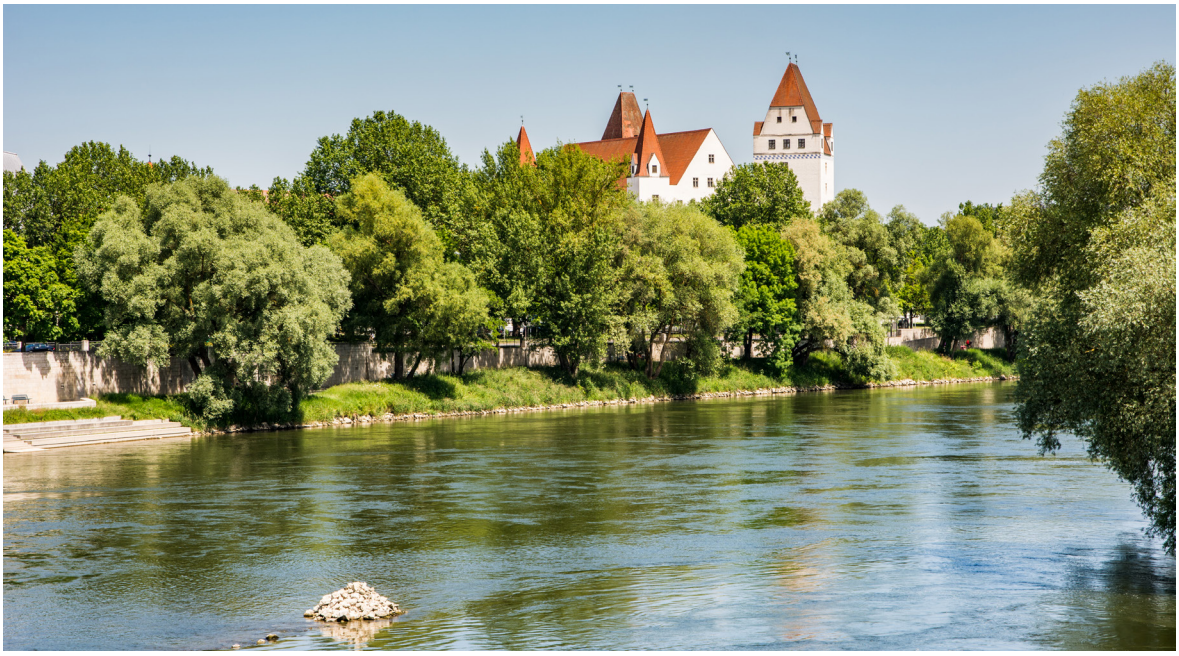
"My team is so proud to be involved in this project, which we believe is the largest ex-refinery remediation task ever undertaken in Germany" said Dr. Rüdiger Recknagel, Chief Environmental Officer at Audi. During more than four decades of operations at the refinery which previously existed on this site, there were occasional spillages of oil and other chemicals. This is the legacy which the IN-Campus team are now working to remediate. "Our environmental management experts know that it is a once in a lifetime opportunity to return such a beautiful piece of land bordering the river Danube to its pristine condition. And I am immensely proud of them because they are working so responsibly and achieving all our milestones. For example, the workforce has just achieved the milestone of 250,000 hours of incident-free operations since work began in 2016".

"The excellent safety statistics are just one example" continues Recknagel. "We are also working within our budget and proceeding according to our timeline. Up to now, we have cleaned-up about 400,000 tonnes of contaminated soil from the site, which is fractionated into sand and stones in the washing process. That is about 65% of the total requirement. And the technologies that we have chosen are performing as expected to return the site to a very high environmental standard: up to now, they have successfully captured and disposed of 450 Tonnes of hydrocarbon pollutants".

Copyright AUDI AG, Dr. Rüdiger Recknagel, Chief Environmental Officer at Audi, on right

Safety and respect for our natural environment are the heart of the project concept. IN-Campus GmbH, a joint venture between AUDI AG and the

Copyright AUDI AG, Dr. Rüdiger Recknagel, IN-Campus Technology Park Project House (Rendering)



The beautiful Danube River at Ingolstadt

town Ingolstadt, is responsible for the site development. The Managing Director Thomas Vogel explains, how these concepts are also core to the long-term vision: "The innovation campus that will be created on this site will be used to develop emissions-free driving systems such as Audi's range of battery electric vehicles. There will also be a state-of-the art crash test facility to ensure that our cars offer the highest standards of safety for their occupants and other road users".

The necessary remediation of soil and groundwater is planned to be completed by the end of 2022. Ultimately, 15 acres of the ex-refinery site closest to the Danube River will be returned to a natural habitat. The meadows that form the natural riverbank are home to many rare species and the additional habitat will help to secure their future survival of this valuable and diverse flora and fauna.

By 2023 the technology park is scheduled to open. IN-Campus will not only be for use by Audi, it will also become the home for many automotive sector suppliers and service providers. Innovative digitalisation concepts such as autonomous driving and the car-driver user interface will also be developed. With the broader energy transition, industry mega-trends and employment shifts in mind, it's a sign of the times that a European refinery is making way for battery electric vehicle development, a car safety testing centre and automotive focused high-tech ventures.

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