

Introduction

This document answers all the questions that were asked by attendees during Axine’s Spring 2021 webinars and provides additional details now that we have had more time to review everything. If you have any additional questions, please [contact us](#) and an Axine representative will get back to you shortly. You can also tell us about a particular wastewater challenge [here](#) and we will let you know if we can help.

Questions & Answers

Axine Wastewater Pollutant Applications

1) Does it work on all types of API waste?

Every API we have encountered so far has been successfully treated. There are thousands of APIs and we have not tested each one. However, we have tested dozens of APIs across virtually every class of API (e.g., antibiotic, antiparasitic, steroids, analgesics, oncology, etc.) and we have not experienced one yet that we cannot successfully treat with our technology to non-detection levels. Our confidence is based on our experience coupled with the fact that our technology can break extremely stable bonds in organic chemistry such as the C - F bond and the C \equiv N bond.

2) What are some solvents that the Axine system successfully treats?

We can treat virtually any organic solvent. Examples of solvents we have experience successfully treating include isopropyl alcohol, acetone, methylene chloride, acetonitrile, toluene, and ethanol.

3) Can you name five organics or co-contaminants that the Axine system destroys?

Here are a few examples, n-methyl-2-pyrrolidone (NMP), Phenol, PFAS, PFOS, PFOA, various chlorinated organics, various surfactants, various detergents, pesticides, and herbicides.

4) How are removal levels for 1,4-dioxane?

Dioxane can be removed or destroyed to mineralization or below detection if required.

5) We have a new limit on Diethylamine. Do you have experience with it?

No problem. We can oxidize amines such as diethylamine.

6) Can you treat wastewater classified as hazardous?

Yes, we have experience in the U.S. working with customers that have pollutants classified as RCRA (Resource Conservation and Recovery Act) hazardous waste such as chloroform and methylene chloride. We have successfully supported these customers to secure regulatory approval to treat wastewater contaminated with these RCRA classified hazardous wastes on-site using our technology.

7) Is this applicable for wastewater with high levels of BOD?

Technically speaking, electro-oxidation can be applied to any concentration of BOD. However, if the BOD is particularly high, biological oxidation could be used as a pre-treatment step. This would enable the biological

system to treat the non-biodegradable organics as a first step followed by electro-oxidation to treat the non-biodegradable organics as a second step.

8) How would we find out if your technology will work on my site and on our water?

The best first step is to [send us an email](#) or tell us about your particular wastewater challenge on our [online web form](#) so we can see if we can help.

Axine's Electro-oxidation (EOx) Technology and System Operation

1) How do you handle wastewater with variable composition and volume?

Variable composition and volume of wastewater is common to pharma wastewater applications and it is not a problem for us to design a system to accommodate such variability. It starts with developing a thorough understanding of the wastewater process conditions, composition and volume ranges. This is done through sampling and by working with the site production team. Variability is then factored into influent wastewater to determine a "not-to-exceed" wastewater specification. The treatment system is then designed to accommodate variability using a combination of equalization tank(s) to smooth out high and low ranges, system spare capacity and automation to adjust system operation.

2) What if I expand my production and wastewater volume?

No problem. All unit processes are modular and scalable. We can accommodate expansion for an increase in volume, increase in pollutant concentration and/or the addition of new wastewater streams.

3) Is there an upper limit on the influent concentration of organics treated?

No, not from a technical standpoint.

4) What is the typical timeframe on the x axis?

The x-axis indicates the batch time. In a commercial system, the batch time typically ranges from 4 – 12 hours depending on the specific application and the corresponding system design. Batch time can be varied by adding or removing reactors, which increases or decreases oxidation capacity.

5) What is the average retention time?

There is not an average that can be generally applied. The required treatment time is dependent on several factors and is heavily dependent on organic loading and the organic mass that must be removed to achieve the treatment objective. However, we can size the commercial scale systems to treat batches in whatever timeframe is required by adding additional reactor surface area.

6) How does Axine process stack up against wet air oxidation (WAO) or its catalyzed version cWAO?

Electro-oxidation is a non-selective oxidation technology. In our experience, it can oxidize the most recalcitrant organic compounds that WAO cannot oxidize. Axine is also substantially lower cost than wet air oxidation.

7) What is the fate of the fluorine and chlorine substituents? Evolving F₂ or Cl₂ gas may not be the most environmentally sustainable outcome, despite the desirable destruction of the API. Especially for concentrated source area streams.

When we evaluate each application, we assess the potential for halogens to ensure that the system design and operation manages these risks you describe. For example, with high chloride streams we have operational strategies to ensure chlorine stays in solution and then is chemically neutralized prior to discharge.

8) What is happening if we have inorganics molecules in the wastewater, like Bromine, Chlorine, Iodine?

We have experience with halogens, and we can accommodate them in system design and operation. Halogens may be oxidized, after which they would either stay in solution and would be neutralized before discharge. If halogenated organics are formed, our systems would be designed to oxidize, mineralize, and eliminate them.

9) How does turbidity affect treatment performance?

Turbidity does not affect our electro-oxidation treatment performance unlike other AOP solutions (e.g. UV). Turbidity may be a consideration for pre-treatment unit processes such as RO.

10) Does this technology work for high total dissolved solids (TDS) influent?

Yes, TDS can actually prove helpful in optimizing electro-oxidation efficiency and sometimes we will even add an electrolyte for this purpose.

11) How frequently need to replace electrodes and what if they fail?

Electrodes and their replacement are covered by the service fee, so you do not need to worry about them. They are Axine's responsibility to service, maintain and replace when necessary. We use a range of electrode materials and the service life of electrodes is variable but generally measured in years. We maintain an inventory of spare electrodes and monitor electrode health 24x7. Electrode health is monitored continuously, and we have lots of advance warning for replacement, which ensures there is no interruption to your system operation or production.

12) For all kinds of API's waste is a single type of electrode or are multiple electrodes required?

The number and type of electrodes required for an API application depends on the API composition, concentration, treatment requirement, background matrix, etc.

13) Any idea of electricity kwh/ (kgAPIs removed) or kwh/CODrem ? the cost of electrodes?

Yes. The cost of electrodes is included in the service fee and depends on the type of electrode materials and the application. Electricity consumption is variable depending on a range of including the pollutant type, wastewater composition, treatment requirement, background matrix, etc. Every Axine service proposal includes an estimate of electricity consumption.

14) What waste by-products are produced by your technology?

The only waste by-products generated by our EOx technology are trace volumes of by-product gases (e.g., H₂, N₂, O₂, CO, CO₂). These are benign, extremely low concentrations that are vented to a safe location. We provide a full analysis of these by-product gases during testing and they should not impact your air permit.

15) Does oxidation produce Cl gas?

If high levels of chlorides are present, then the Axine system is designed and operated in a way that ensures no chlorine gas is discharged and any excessive concentration of chlorine in solution is chemically neutralized prior to discharge.

16) Are there noxious odors from the API destruction?

No.

Treatment Performance

1) How do you know the APIs are treated?

We work with customers to design and implement a rigorous treatability, testing and verification program for each application before and after the system is installed. We have extensive experience working with specialized commercial and research labs to analyze APIs.

2) How do you manage the analysis of the treated water? Do you use specific labs, which can deal with the different matrix?

Yes, we have a network of labs capable of analyzing the full range of required background matrix to the required detection limits for any application. In the case of proprietary APIs, custom analytical methods may need to be developed if the customer does not already have them developed for the required background wastewater matrix (e.g., has the method already developed for QC, but not for wastewater).

3) What are the performance specs that are measured? pH? What else?

We measure a wide range of on-line performance specifications including pH, temperature, flow rate, ORP (oxidation-reduction potential), conductivity, voltage, current and many others. Collectively, these performance specs comprise the unique “fingerprint” for each application that is monitored remotely by our Network Operating Center (NOC). The offline parameters that are routinely measured include COD, TOC, and the target contaminants, which provide validation of the fingerprint.

4) Do you support analytical verification of multiple API reduction? Is MOA for multiple APIs an issue?

Yes. For generic APIs we will often rely on existing analytical methods. For proprietary APIs we can collaborate with you to develop a proper understanding of the background matrix to develop wastewater analytical methods from your existing methods. We can also support wastewater analysis using specialized lab facilities with API analytical capabilities. We do multi-API treatment projects regularly.

5) How does your performance guarantee work?

First, we collaborate with customers to establish an influent specification of the wastewater coming into the Axine system and the treatment specification for the water exiting the Axine system. Second, we test the wastewater to verify performance. Third, we design a custom treatment system where we guarantee to meet the treatment specification provided that we are operating on wastewater with the influent spec, including safety factors/redundancy. Both specifications are included in the service agreement.

Permitting

1) What permitting is typically required?

This depends on your existing discharge permit and regulations. Typically, you will require some form of permit amendment, modification, or notification to local regulators. However, it is unlikely you will require a new permit unless the wastewater is a new stream generated by a newly constructed facility. Axine has a lot of experience in this area and can guide you through the process with all necessary technical support to ensure successful permitting.

2) I see a stack on the unit. Is there air permitting requirements?

The purpose of the stack is to direct the trace, by-product gases to a safe location. Air permitting is not typically required.

Installation & Operations

1) How long does it take to get an Axine system installed and operating at my site?

From signed service agreement, it typically takes 4 to 6 months to installation and full operation of an Axine system at your site.

2) What kind of system uptime do you have and how do you ensure no service interruption?

Under terms of our service agreements, we are providing a de facto guarantee to treat a certain volume per day, per year depending on the application. This means we work with you to understand your requirements and then design our system with sufficient capacity and redundancy to ensure we meet our production obligations – and ensure we are never a bottleneck in your operations. We also monitor system operation 24.7 so that we can proactively manage any maintenance issues and dispatch local service resources.

3) Is the system mobile? So, can it easily be moved from one location to another?

Yes. Our systems are mobile. No, we do not recommend moving them from one location to another. This is because our systems custom designed for each individual application and integrated into site operations with required utility interconnections (e.g., power, water, etc.).

Maintenance & Service

1) What kind of site or local operations support is required for your system?

Systems are fully automated and remotely monitored 24x7 by Axine from our Vancouver-based Network Operations Centre (NOC) with key performance data communicated to your site DCS. Level 1 routine service and maintenance is typically handled by local service contractors (can be by site if requested). Level 2 system upgrades are handled by Axine's dedicated service operations team. Emergency response is provided by both.

2) With your service model, how much on-site support is typical?

The level of on-site support can be tailored to site needs. Axine can handle 100% of all system operation, service, and maintenance. In other cases, customers can provide a limited base level of system operation. We are flexible and work with customers to define service level scope for each project.

System Costs

1) Can you please give typical investment and operating costs?

There is no typical service fee or operating cost. Service fees are variable depending on influent wastewater volume and composition, target pollutant, treatment requirement, background matrix, pre and/or post treatment requirements, electricity costs, etc. We routinely prepare service estimate at no cost for customers. Please [let us know](#) if there is a specific application, you would like us to evaluate.

Regional Focus

1) Are you restricted to work only in North America?

No, we support pharma customers globally.

2) Do you have some installations like the one you presented in Europe? In which country?

We expect to have EU installations very soon.

3) Is Axine working in India?

Yes. Axine can support projects in India.

General

1) Is Axine an established company and how long have you been around?

Yes, Axine was formed in 2012 and is a fully established company with a professional team, fully commercialized technology and numerous commercial projects and operations. We continue to grow and serve the global pharmaceutical industry.

2) Can you clarify the title "Driving to ZERO in Pharma Manufacturing Wastewater" of this talk? Are we to assume you mean zero risk, not zero discharge?

The "Driving to ZERO" theme convey our long-term aspiration for pharmaceutical manufacturing wastewater including the drive to *zero* pharmaceuticals in the environment (from manufacturing), *zero* API emissions, *zero* liquid discharge, *zero* off-site trucking and incineration and yes, ultimately *zero* (or greatly reduced) risk. As expressed during the webinar, we believe Axine will play a pivotal role in helping the industry achieve these goals.