

Electrochemical Oxidation of Active Pharmaceutical Ingredients (APIs) in Manufacturing Wastewater

Pharmaceuticals in the Environment

Pharmaceutical medicines play a critical role in human and animal health. In recent years, increasing evidence indicates that pharmaceuticals are accumulating in the environment and creating risks to human health and the environment. To address these risks, the pharmaceutical industry along with other stakeholders have committed to developing and implementing solutions to reduce the impact of pharmaceuticals in the environment (PIE).

Pharmaceuticals can reach the environment through several pathways including use and excretion by humans and animals, disposal of unused or expired medication and effluent from pharmaceutical manufacturing facilities. Axine Water Technologies



Axine Value Proposition



Complete mineralization of all types of APIs to below PNEC levels



Lowest cost and most versatile solution for API treatment without hazardous chemicals



Eliminate off-site trucking and incineration of API contaminated CIP rinse water



Treats APIs in whole plant effluent to ensure site compliance with PNEC values

has created a new standard for addressing the third pathway to eliminate APIs in manufacturing wastewater.

This bulletin summarizes the performance of Axine's electrochemical oxidation technology for treating active pharmaceutical ingredients (APIs) commonly found in clean-in-place (CIP) rinse streams and wastewater effluent generated by pharmaceutical manufacturing facilities. APIs tested by Axine include antibiotics, antimicrobials, pain and chemotherapy medicines. In all cases, the results show that Axine's technology treated APIs to below site requirements, below Predicted No-Effect Concentration (PNEC¹) values and/or below analytical detection limits².

¹ PNECs are rigorous, risk-based and science-based, industry recommended targets for discharge API concentrations that are safe for receiving ecosystems.

² While analytical detection limits are stated, note they vary by analytical method, interference, conditions and operator preference.

Axine's Electrochemical Solution

APIs in wastewater are challenging to treat with conventional technologies because they are highly stable, often recalcitrant and non-biodegradable. In many cases, conventional wastewater technologies such as biological, sorption and advanced oxidation processes (AOP) are ineffective at treating APIs to the levels required to minimize impact to the environment. Frequently, pharmaceutical plants have no other option but to truck API contaminated streams off-site so the APIs can be thermally oxidized in an incinerator.

Axine has commercialized a unique, proprietary electrochemical oxidation technology ideally suited to oxidize all types of APIs in pharmaceutical wastewater to below PNEC levels. Axine's technology applies electricity to solid state electrodes made from advanced catalyst materials. The Axine process mineralizes and destroys all types of APIs to below PNEC levels through multiple oxidation mechanisms.

Axine's technology does not use hazardous chemicals and does not produce any solid or liquid waste. By comparison, conventional AOP technologies (e.g. ozone and hydrogen peroxide) may not be able to achieve complete destruction of APIs to meet stringent PNEC values and avoid producing toxic oxidation by-products. Conventional AOP technologies also require the use of hazardous chemicals.

Axine packages its electrochemical oxidation technology with other wastewater processes (e.g. membranes, filtration, etc.) to provide complete turnkey solutions under a service model with performance guarantees. By taking this approach, Axine provides pharmaceutical manufacturers with a robust solution to achieve risk quotients less than 1 and low PNEC levels for the most ecotoxic APIs.



API Treatability Tests

Axine has conducted treatability tests on a wide range of APIs commonly produced by the pharmaceutical industry with molecular weights from less than 200.00 g/mol to greater than 800.00 g/mol. Select test results are summarized below.

Test #1: Antimicrobial API

Treatability testing was conducted on a CIP rinse stream with background COD of > 3,000 mg/L and 7,000 µg/L of an antimicrobial API. The antimicrobial, which is toxic to aquatic ecosystems, has a multiple-ring structure and a molecular weight of more than 500 g/mol. As shown in Table 1 and Figure 1, Axine successfully treated the API to > 99.2% reduction or < 50 µg/L, which is below the 70 µg/L on-site treatment requirement for discharge to sewer.

Parameter	Units	Before Treatment	Treatment Required	Axine Treated	% Reduction
API	µg/L	7,000	70	< 50*	> 99.2%
COD	mg/L	3,250	N/A	< 50*	> 98.4%

Table 1: API and COD concentrations before and after Axine treatment of an antimicrobial API

*Values indicate the analytical detection limits of these compounds

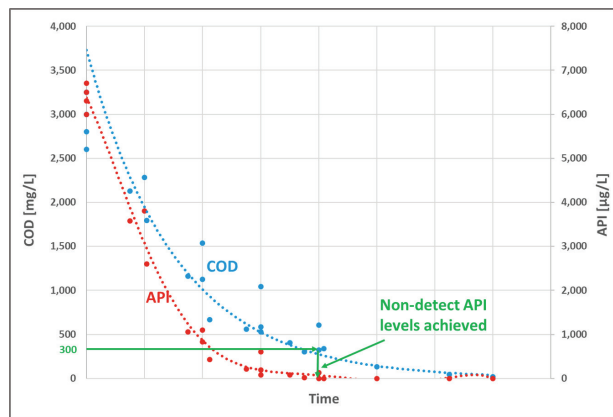


Figure 1: Treatment reduction curves for API and COD concentrations before, during and after Axine treatment of an antimicrobial API

Test #2: Antibiotic API

Treatability testing was conducted on model wastewater containing deionized (DI) water with 100,000 µg/L of Amoxicillin and a COD of 134 mg/L. Amoxicillin is a common antibiotic with a molecular weight of 365.40 g/mol. As shown in Table 2 and Figure 2, Axine successfully treated the Amoxicillin to > 99.9% reduction or < 0.1 µg/L, which is below the PNEC value of 0.25 µg/L and the analytical detection limit of 0.1 µg/L.

Parameter	Units	Before Treatment	PNEC	Axine Treated	% Reduction
API	µg/L	100,000	0.25 ^A	< 0.1*	> 99.9%
COD	mg/L	134	N/A	< 10*	> 92.5%

Table 2: API and COD concentrations before and after Axine treatment of Amoxicillin

*Values indicate the analytical detection limits of these compounds

^AValues per Temple University's Water and Environmental Technology (WET) Center PNEC list, 2019

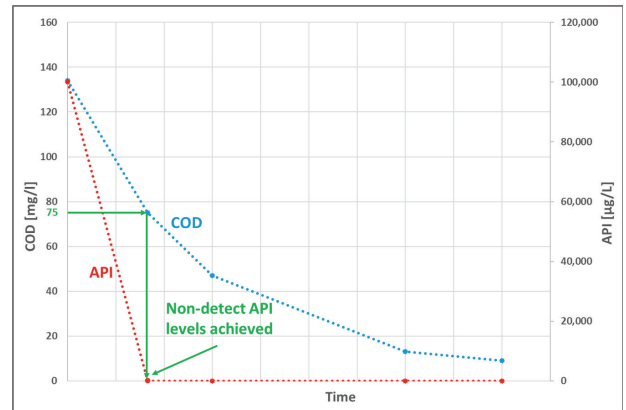


Figure 2: Treatment reduction curves for API and COD concentrations before, during and after Axine treatment of Amoxicillin

Test #3: Chemotherapy API

Treatability testing was conducted on CIP process rinse water with 7,800 µg/L of a chemotherapy API and background COD of 19,920 mg/L. The API has a molecular weight of over 800 g/mol. As shown in Table 3 and Figure 3, Axine successfully treated the chemotherapy medicine to > 99.3% reduction or < 50 µg/L, which is well below the plant treatment target of < 200 µg/L.

Parameter	Units	Before Treatment	Treatment Required	Axine Treated	% Reduction
API	µg/L	7,800	200	< 50*	> 99.3%
COD	mg/L	19,920	N/A	920	> 95.3%

Table 3: API and COD concentrations before and after Axine treatment of a chemotherapy API

*Value indicates the analytical detection limit of this API

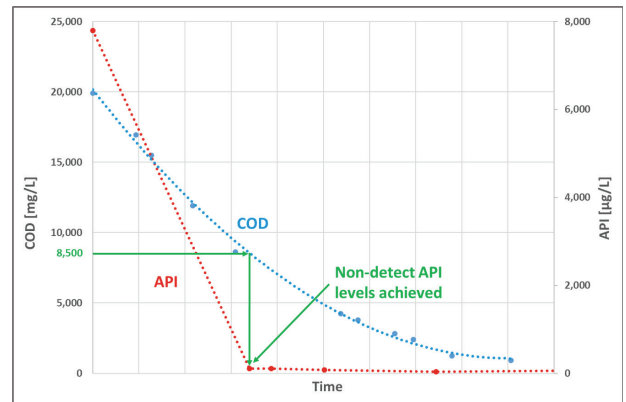


Figure 3: Treatment reduction curves for API and COD concentrations before, during and after Axine treatment of a chemotherapy API

Test #4: API Blend

Treatability testing was conducted on model wastewater with a background solvent matrix and 102,000 µg/L of Acetaminophen (pain medicine), 1,320,000 µg/L of Ampicillin (antibiotic), 71,000 µg/L of Atorvastatin (cardiovascular disease prevention), 94,000 µg/L of Atenolol (beta blocker) and 75,000 µg/L of Roxithromycin (antibiotic). Molecular weights ranged from 151.16 to 837.05 g/mol. This test was designed to simulate conditions where waste streams contain multiple APIs. As shown in Table 4, Axine successfully treated all APIs to > 99.999% reduction, below PNEC values and below analytical detection limits.

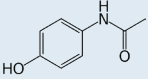
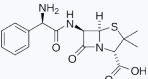
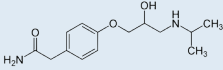
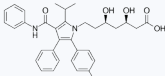
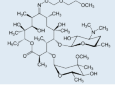
Parameter	Molecular Weight	Molecular Structure	Units	Before Treatment	PNEC	Axine Treated	% Reduction
Acetaminophen	151.16 g/mol		µg/L	102,000	95 ^B	< 0.2*	> 99.9998%
Ampicillin	349.41 g/mol		µg/L	1,320,000	0.25 ^A	< 0.2*	> 99.9999%
Atenolol	266.34 g/mol		µg/L	94,000	148 ^B	< 0.05*	> 99.9998%
Atorvastatin	558.64 g/mol		µg/L	71,000	14 ^B	< 0.005*	> 99.9999%
Roxithromycin	837.05 g/mol		µg/L	75,000	1 ^A	< 0.005*	> 99.9999%

Table 4: API concentrations before and after Axine treatment in a multiple API blend

^AValues per Temple University's Water and Environmental Technology (WET) Center PNEC list, 2019

^BValues per AMR Industry Alliance's recommendation, 2019

*Values indicate the analytical detection limits of these compounds

Conclusion

The selected API treatability results presented in this bulletin demonstrate the performance of Axine's technology for treating diverse APIs to below site requirements, below PNEC values and/or below analytical detection limits. Axine's technology and service delivery model provide pharmaceutical manufacturers with a solution capable of treating all types of APIs at high performance and low cost compared to conventional AOP and other technologies. Axine's technology can be applied to a range of pharmaceutical applications including treating APIs and other organics in CIP rinse streams to avoid off-site incineration, pretreating API contaminated streams before on-site wastewater treatment and treating APIs in whole plant effluent prior to discharge.

About Axine

Axine has created a new standard for treating toxic, recalcitrant organic pollutants in pharmaceutical, chemical and other industrial wastewater to address a global problem. Axine's breakthrough solution combines advanced electrochemical oxidation technology with a flexible, modular system design and a unique wastewater-as-a-service business model. Axine provides customers with a robust, versatile solution capable of treating all types of organics to meet the most stringent treatment requirements without using hazardous chemicals. Axine's service model enables customers to achieve wastewater and sustainability goals with minimal capital investment and technology risk. For more information, please visit www.axinewater.com

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