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PHARMACEUTICAL DRUG DISPOSAL SYSTEM - RX DESTROYER™ ALL-PURPOSE

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Revision Details

Revision	Date	Reviewed by	Approved by	Comments

Executive Summary

C2R Global Manufacturing Inc. contracted HRL Technology Group Pty Ltd to evaluate the efficacy of a pharmaceutical drug disposal system, called the 'Rx Destroyer All-Purpose.'

This report examined a combination of Activated Carbon and a proprietary liquid agent, "Rx Destroyer™," to safely dissolve, deactivate, and adsorb pharmaceutical drugs.

The Rx Destroyer™ All-Purpose is an effective device to deactivate API's. Most API's were completely (at least > 98 %, typically > 99.7 %) adsorbed within the first 24 hours.

The adsorption curves all indicate typical first-order reaction kinetics following the standard first-order reaction half-life decay equation.

All the API's were adsorbed by the Rx-Destroyer™ All-Purpose, mostly within the first day; some API's required longer absorption periods. The Rx-Destroyer™ All-Purpose is an excellent tool for disposing of pharmaceuticals, ensuring that the active ingredients will not be retrievable by common means available to the general public, and nor will the ingredients easily land up in the environment.

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1 Introduction

C2R Global Manufacturing Inc. (hereafter referred to as C2R) contracted HRL Technology Group Pty Ltd (hereafter referred to as HRL) to evaluate the efficacy of a pharmaceutical drug disposal system, called the 'Rx Destroyer All-Purpose.'

The pharmaceutical drug disposal system is based on the principle that activated carbon adsorbs a large variety of chemicals on its surface; activated carbon usually has a huge surface area, often in excess of one thousand square metres per gram.

There are several specific applications of pharmaceutical drug disposal systems:

1. Reduce the environmental and biological impact of pharmaceutical drugs
2. Reduce the illicit use of pharmaceutical drugs
3. Reduce the availability of illicit pharmaceutical drugs
4. Reduce the inadvertent intake of pharmaceutical drugs by children, mentally handicapped persons, or other people with other frailties or disabilities
5. Safe disposal at various facilities, including
    a. pharmacies (drug stores),
    b. aged care facilities,
    c. care facilities for frail or handicapped persons,
    d. police stations,
    e. hospitals,
    f. clinics,
    g. and various other facilities where pharmaceutical drugs need disposal

This report examined a combination of Activated Carbon and a proprietary liquid agent, "Rx Destroyer™" to safely dissolve, deactivate, and adsorb pharmaceutical drugs.

Please note that in some literature the terms 'Activated Charcoal,' 'Activated Carbon,' and 'Active Carbon' are used interchangeably.

2 Overview

This study focused on the following areas of interest:

1. Previous Literature reviews
2. The time to deactivate several model Active Pharmaceutical Ingredients (API's)

3 Literature Review

The literature overview focused on the traditional use of Activated Carbon, and how it supports the use of Activated Carbon as an adsorbent of pharmaceutical drugs, as well as other, similar compounds.

3.1 Book: Activated Carbon by Harry Marsh & Francisco Rodríguez Reinoso

ISBN: 9780080455969, 0080455964
Page count: 554
Published: 12 July 2006
Format: E-book
Publisher: Elsevier Science
Language: English
Author: Harry Marsh, Francisco Rodríguez Reinoso
Editor: Francisco Rodríguez Reinoso

This book refers to Activated Carbon as being 'as old as history itself and would be known to Hippocrates, the father of medicine. The earliest recorded applications include their use as a medicine to relieve digestion problems which continue today in the removal of overdoses of drugs from stomachs.'

This book also indicates that the 'most dramatic application of charcoal was in World War I with its use in gas masks for the protection of soldiers against chlorine, phosgene, and mustard gas in trench warfare… It was reported at that time that these respirators were more effective against chlorine (Cl_2) and phosgene ($COCl_2$) than with mustard gas (1,1-thiobis(2-chloroethane)) … because of its size and shape, would be adsorbed more slowly than the smaller molecules of chlorine and phosgene.'

The authors describe some tests that are generally used to determine the suitability of Activated Carbon for its intended use. Test methods have been developed and approved by various organisations and the methods are freely available. These organisations include:

- American Society for Testing Materials (ASTM)
- The American Water Works Association (AWWA)
- The International Organization for Standardization (ISO)
- The Deutches Institut für Normung (DIN)

Some of the tests include:

- Physical Characterisation
  - Bulk Density
  - Real Density
  - Apparent Density
  - Particle Size Distribution

- Mechanical Strength
- Chemical Characterisation
  - Moisture Content
  - Ash Content
  - Ignition Temperature (kindling point)
  - Self-Ignition Test
  - pH Value
  - Water-Soluble Content
- Adsorption Characterisation
  - Carbon Tetrachloride Activity
  - Benzene Adsorption
  - Iodine Adsorption
  - Methylene Blue Adsorption
  - Phenol Adsorption
  - Molasses Decolourisation
  - Butane Adsorption
  - Phenazone Adsorption
  - Specific Surface Area (BET Test, i.e., Brunauer–Emmett–Teller theory)

3.2 Book: Activated Carbon Adsorption by Roop Chand Bansal & Meenakshi Goyal

ISBN: 9781420028812, 1420028812
Page count: 520
Published: 24 May 2005
Format: E-book
Publisher: Taylor & Francis
Language: English
Author: Roop Chand Bansal, Meenakshi Goyal

The authors of this book list some of the following areas as typical liquid-phase applications:

- Food processing
- Preparation of Alcoholic Beverages
- Decolourising of Oils and Fats
- Sugar Industry
- Pharmaceutical Industry
- Recovery of Gold
- Purification of Electrolytic Baths
- Purification of Liquid Fuels

Some more specific applications are listed in Chapter 7 of the book, under the heading of ‘Activated Carbon Adsorption and Environment: Adsorptive Removal of Organics from Water’

- Activated Carbon Adsorption of Halogenated Organic Compounds
- Activated Carbon Adsorption of Natural Organic Matter (NOM)
- Activated Carbon Adsorption of Phenolic Compounds
- Adsorption of Nitro and Amino Compounds
- Adsorption of Pesticides
- Adsorption of Dyes
- Activated Carbon Adsorption of Drugs and Toxins
- Adsorption of Miscellaneous Organic Compounds

Once again, the authors mention that 'The activated carbon adsorption of synthetic drugs have been studied with a view to removing them from the human body when taken in excess…'

3.3 Book: Activated Carbon Surfaces in Environmental Remediation by Teresa J. Bandosz

ISBN: 9780080455952, 0080455956
Page count: 588
Published: 27 February 2006
Format: E-book
Publisher: Elsevier Science
Language: English
Author: Teresa J. Bandosz
Editor: Teresa J. Bandosz

The author discusses the use of Activated Carbons as Medical Adsorbents in more detail than the previous authors and mentions that 'Activated Carbons have been used in medicine since ancient times.' The author refers to another book (described in paragraph 3.4 in this report), 'Activated Charcoal in Medical Applications' by David O. Cooney which details activated charcoal's great effectiveness in treating drug overdoses and poisonings in both humans and animals, as well as activated charcoal's ability to reduce the systemic absorption of a vast array of drugs, chemicals, and biochemical substances-including analgesics, antipyretics, sedatives, alkaloids, snake venoms, and bacterial and fungal toxins.

The authors list a table (page 536, Table 1) titled 'Toxic Organic Substances and Drugs Adsorbed by Activated Carbon' and list some of the following types of poisons which can be adsorbed (specifically in humans, but also in animals): strychnine, aspirin, acetaminophen, propoxyphene, phenobarbital, barbital, zolpidem, carbamazepine, mefenamic acid, piroxicam, phenylbutazone, indomethacin, imipramine, desipramine, nortriptyline, doxepin, furosemide, and many more.

3.4 Book: Activated Charcoal in Medical Applications by David O. Cooney

ISBN: 9780367401917, 0367401916
Page count: 608
Published: 23 September 2019
Format: Paperback
Publisher's Press LLC
Language: English
Author: David O. Cooney

The publisher of this book describes it as highlighting activated charcoal's great effectiveness in treating drug overdoses and poisonings in both humans and animals, and this comprehensive, single-source reference brings together vital information from every significant study on the use of activated charcoal for medical purposes – describing all available charcoal products and their characteristics.

The book details activated charcoal's ability to reduce the systemic absorption of a vast array of drugs, chemicals, and biochemical substances – including analgesics, antipyretics, sedatives, alkaloids, snake venoms, and bacterial and fungal toxins.

3.5 Book: Activated Charcoal Antidote, Remedy and Health Aid by David O. Cooney

ISBN: 9781479603367, 1479603368
Page count: 102
Published: 6 October 2016
Publisher: TEACH Services, Inc.
Language: English
Author: David O. Cooney

In this book, the author gives an overview of the medical applications of Activated Carbon. The author lists proven applications of Activated Carbon in Chapter 5 under the heading 'Effects of Activated Charcoal on Various Types of Drugs and Poisons.' The list includes the following and some other chemicals:

- Common Household Chemicals
- Alkaloids
- Aspirin and Other Salicylates
- Acetaminophen
- Hypnotics and Sedatives
- Tricyclic Antidepressants
- Cardiac Glycosides

The author describes more details regarding research done on hypnotics and sedatives, specifically works done by Anderson in 1948, Picchioni's research group in 1966, and later works done by Picchioni, Chin, and Laird in 1974. Other works are listed. The research works indicate, in general, that 'It is clear than the charcoal, …, was effective in lowering blood drug levels.'

3.6 Scientific Publication: Management of Acute Poisoning with Activated Charcoal by Donald G. Corby & Walter J. Decker

Publication: Pediatrics
Authors: Donald G. Corby & Walter J. Decker
Date: September 1974
Volume: 54 (3)
Pages: 324-329

In this publication, the authors found that 100 % adsorption of 10 capsules and 85 % adsorption of 20 capsules (each capsule = 32 mg propoxyphene) after only 20 minutes in a 150 mL solution of simulated gastric juice to which 5 grammes of activated charcoal had been added.

3.7 Scientific Publication: Activated Carbon-Based System for the Disposal of Psychoactive Medications by Song et al

Publication: Pharmaceutics
Authors: Song Y, Manian M, Fowler W, Korey A, Kumar Banga A
Date Published: 07 November 2016
Volume: 2016; 8(4):31
doi: 10.3390/pharmaceutics8040031

(This Scientific Paper is Published by MDPI AG, St. Alban-Anlage 66, CH-4052 Basel, Switzerland)

The authors mention that 'Activated carbon is obtained by thermal decomposition of carbon-based materials such as coal, coconut, or wood. The purpose of this activation procedure is to achieve a high internal surface area which is good for the adsorption of the drug from the formulation to the activated carbon. This large surface area is due to the presence of small, low volume pores on the charcoal where the pore size distribution contributes to the efficiency of the activated carbon in the drug adsorption. Activated carbon has numerous micropores in comparison to charcoal which provides maximum bonding surface area for drug binding. This granular activated carbon is already being used in water treatment processes for removal of micropollutants including pharmaceuticals and endocrine disruptors.'

The authors concluded their study by saying that 'The effectiveness of the activated carbon-based drug disposal system was examined using three model psychoactive medications. The deactivation system successfully adsorbed and deactivated about 70 % of the psychoactive medications by 8 h and more than 99 % within 28 days and did not release adsorbed drug substances when exposed to large volumes of water or 30 % ethanol. Thus, this unique system is simple, safe, and user-friendly for patients who can deactivate unused or expired psychoactive medications from the comfort of their homes.'

The authors proved that the drugs are irreversibly adsorbed onto the Activated Carbon and cannot be removed by means generally available to the general public.

3.8 Summary of Literature Review

It is evident from the literature study that a wide range of pharmaceutical drugs, and many other organic and inorganic chemicals, can be adsorbed onto Activated Carbon. Activated Carbon is commonly used in medical fields to adsorb various chemicals to reduce toxicity (e.g., after an overdose).

Activated Carbon has been proven to adsorb large amounts of pharmaceuticals from aqueous media (e.g., simulated gastric juice) with small amounts of Activated Carbon in a matter of minutes.

Pharmaceutical drugs that have been adsorbed onto Activated Carbon are not easily removed by solvents like water or ethanol.

The use of Activated Carbon seems to be a natural choice in the use of Pharmaceutical Drug Disposal systems.

4 Materials used in this Study

4.1 Activate Carbon

The Activated Carbon used in this study was supplied by C2R.

4.2 Rx Destroyer Proprietary Solution

The Rx Destroyer solution was supplied by C2R. The solution is described in the Safety Data Sheet (SDS) as a mixture consisting of non-regulated materials.

4.3 Active Pharmaceutical Ingredients

A range of highly scheduled API's, mainly opioids, was selected to cover the typical field of application of this device. The following API's were investigated:

- Morphine
- Dilaudid (Hydromorphone)
- Oxycodone
- Fentanyl
- Propofol

Opioids are a group of medicines that may be prescribed to treat pain. Opioids reduce feelings of pain by interrupting the way nerves signal pain between the brain and the body. Sometimes opioids are taken after being obtained illegally for non-prescribed use.

Opioids work by interacting with the opioid receptors in your brain. This can have several effects, including altering how you feel pain.

4.3.1 Morphine

Morphine is used to relieve severe pain, such as pain caused by a major trauma or surgery, labour pain in childbirth or cancer pain.

Morphine should only be used where other forms of pain relief have not been successful in managing pain or are not tolerated.

Morphine works directly on opioid receptors in the central nervous system and reduces feelings of pain by interrupting the way nerves signal pain between the brain and the body.

It is available in tablet, capsule, granule, oral liquid, and injection formulations.

4.3.2 Dilaudid (Hydromorphone)

Hydromorphone is used for the short-term relief of severe pain, whereas other pain medicines have been ineffective or cannot be used. It is more potent than morphine and should only be used under specialist medical supervision.

Hydromorphone should also be used only when other forms of pain relief have not been successful in managing pain.

Hydromorphone works directly on opioid receptors in the central nervous system and reduces feelings of pain by interrupting the way nerves signal pain between the brain and the body.

It is available as tablets, an oral liquid, or injections.

Hydromorphone should only be used in limited circumstances under specialist medical care.

4.3.3 Oxycodone

Oxycodone is used to relieve moderate to severe pain. It should only be used when other forms of non-opioid pain relief have not been successful in managing pain or are not tolerated.

Oxycodone is not usually recommended for the treatment of chronic pain.

Oxycodone works directly on opioid receptors in the central nervous system and reduces feelings of pain by interrupting the way nerves signal pain between the brain and the body.

It is available in tablet and injection formulations.

4.3.4 Fentanyl

Fentanyl is used to treat acute pain caused by major trauma or surgery, as well as chronic pain caused by cancer.

How long you need to take fentanyl will depend on why it has been prescribed. For example, fentanyl patches for cancer pain or in people receiving palliative care are approved for life-long use, while fentanyl used in acute pain or anaesthesia will be used only for a short time.

Fentanyl works directly on opioid receptors in the central nervous system and reduces feelings of pain by interrupting the way nerves signal pain between the brain and the body.

It is available in several formulations in different strengths, including patches, lozenges, tablets that disintegrate in your mouth and sublingual tablets. Fentanyl is also given by injection for severe acute pain or as part of anaesthesia before surgery.

4.3.5 Propofol

- Induction of General Anaesthesia in Children and Adults
    - Propofol is a short-acting intravenous anaesthetic agent suitable for induction of general anaesthesia in adults and children aged one month and older
- Maintenance of General Anaesthesia in Children and Adults
    - Propofol is a short-acting intravenous anaesthetic agent suitable for maintenance of general anaesthesia in adults and children aged 3 years and older. Propofol may also be used for maintenance of general anaesthesia in children aged from one month to 3 years for procedures not exceeding 60 minutes unless alternative anaesthetic agents should be avoided.
- Propofol has no analgesic properties.
- Use for Sedation During Intensive Care in Adults
    - Propofol may also be used in patients >16 years for sedation of ventilated patients receiving intensive care.
- Conscious Sedation for Surgical and diagnostic Procedures
    - Propofol may also be used for monitored conscious sedation for surgical and diagnostic procedures in adults and children aged one month and older

This medication is administered intravenously. It appears as a milky white, oil-in-water emulsion, in a colourless glass ampule.

5 Experimental Setup

5.1 Components and Specified Ratios

C2R prescribed the components and their specific proportionate ratios; the exact proportionate ratios were used to scale down to an experimental level.

The Activated Carbon, Rx Destroyer™ Liquid, and API's were weighed into 50 mL Cell Culture Flasks. The reasoning behind using cell culture flasks as a reaction vessel was to easily observe the actions in the flask, and to allow for enough area to operate as the device may usually do.

The various materials were weighed out separately and added together promptly. We noted the starting time.

5.2 Sampling at Specified Intervals

The API's were left in contact with the Activated Carbon and Rx Destroyer™ Liquid for predetermined periods and very small subsamples were extracted at the appropriate time intervals.

The time intervals were designed to determine the reaction kinetics – that is the rate at which the API's adsorb onto the Activated Carbon. The time intervals were 1 hour, 2 hours, 4, 8, 24, 48, 96, and 168 hours. The amount of material adsorbed onto could be determined by analysing the concentration of the active ingredients in the retrieved subsample. The subsamples were placed into an HPLC liquid vial and diluted with water; the vials were tightly closed and stored until analysis.

5.3 Agitation

C2R requested that the samples should be agitated regularly; the samples were agitated right before the sampling event, and then lightly agitated again immediately afterwards (to ensure the material is settled in an even layer).

6 Analytical Methods

6.1 Reference Material for Calibration

The laboratory personnel calibrated the instruments using various dilutions of the original Pharmaceuticals, as they were purchased from the supplier.

6.2 Instrumentation

Two types of instruments were used for the analyses of these samples, depending on the concentration levels, and the type of API.

6.2.1 HPLC

Morphine, Dilaudid, Propofol, and Oxycodone were determined using High-Performance Liquid Chromatography (HPLC) with Ultraviolet Spectrometric (UV) detection.

6.2.2 LC-MS/MS

Fentanyl was determined using Liquid Chromatography with Tandem Mass Spectrometry detection (LC-MS/MS) because of the complexity and very low concentration range.

7 Analysis Results

7.1 Results

Figure 1, below, shows the amount of adsorption of the API's against the contact time.

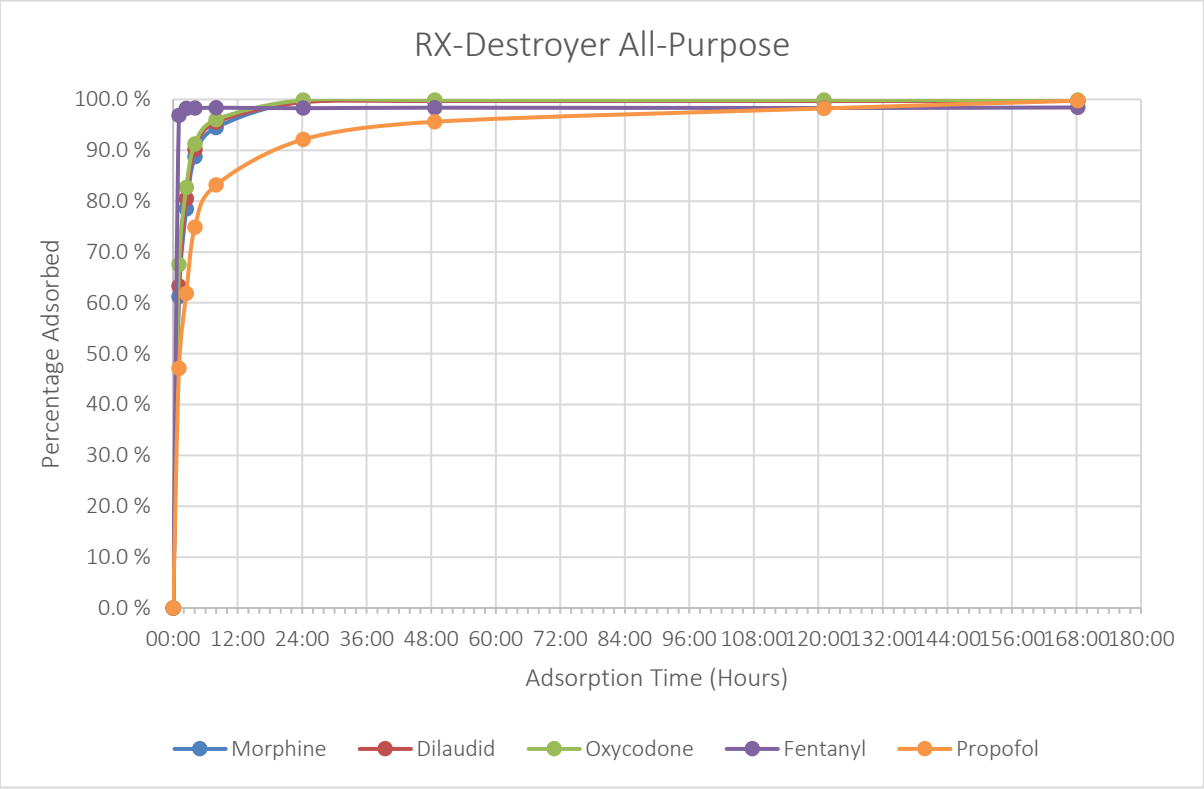

Figure 1: Adsorption of API's vs Contact Time

8 General Discussion

The Rx Destroyer™ All-Purpose is an effective device to deactivate API's. It is evident from the graph in Figure 1 (above) that most API's are completely (at least > 98 %, typically > 99.7 %) adsorbed within the first 24 hours. The only API that required a longer adsorption time was the Propofol, which required more than 120 hours (5 days) to adsorb completely (> 99.7 %).

8.1 Conclusion

In short: all the API's were adsorbed by the Rx-Destroyer™ All-Purpose, mostly within the first day; some API's required longer absorption periods. The Rx-Destroyer™ All-Purpose is an excellent tool for disposing of pharmaceuticals, ensuring that the active ingredients will not be retrievable by common means available to the general public, and nor will the ingredients easily land up in the environment.