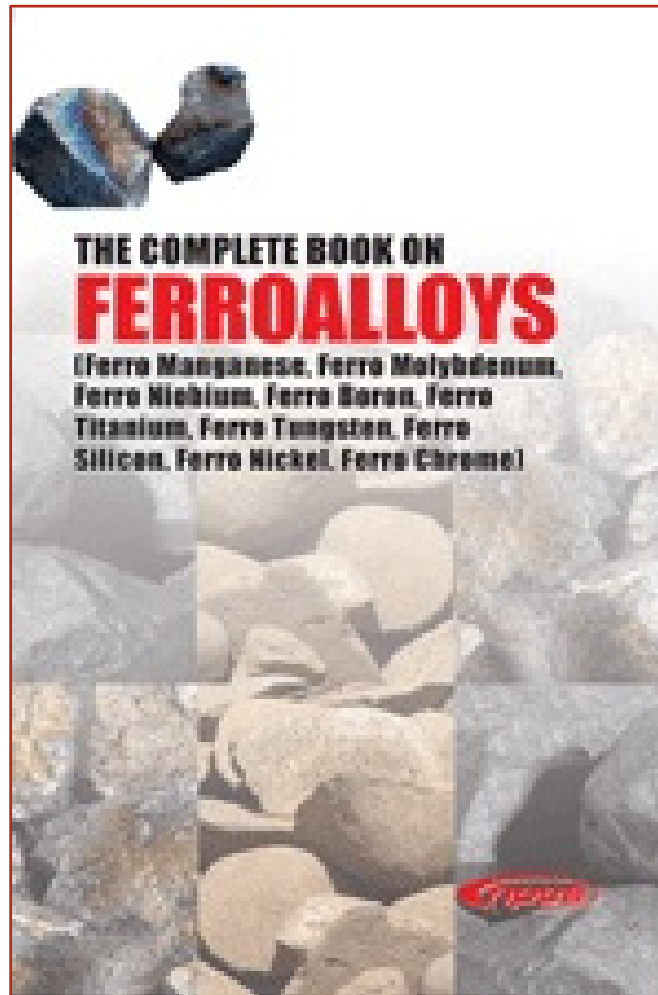


# Ferroalloys

*(Ferro Manganese, Ferro Molybdenum, Ferro Niobium, Ferro Boron, Ferro Titanium, Ferro Tungsten, Ferro Silicon, Ferro Nickel, Ferro Chrome)*



# INFORMATION ABOUT THE BOOK

***Title:*** The Complete Book on Ferroalloys

(Ferro Manganese, Ferro Molybdenum, Ferro Niobium, Ferro Boron,  
Ferro Titanium, Ferro Tungsten, Ferro Silicon, Ferro Nickel, Ferro Chrome)

***Format:*** Paperback

***ISBN:*** 9789381039298

***Code:*** ENI258

***Pages:*** 480

***Published:*** 2014

***Publisher:*** NIIR PROJECT CONSULTANCY SERVICES

An alloy is a mixture or solid solution composed of metals. Similarly, Ferroalloys are the mixture of Iron with high proportion of other elements like manganese, aluminium or silicon. Alloying improves the physical properties like density, reactivity, Young's modulus, electrical and thermal conductivity etc. Ferroalloys thus show different properties as mixture of different metals in different proportion exhibit a wide range of properties. Also, Alloying is done to alter the mechanical properties of the base metal, to induce hardness, toughness, ductility etc.

The main demand of ferroalloys, nowadays is continuously increasing as the major use of such products are in the field of civil construction; decorative items; automobile; steel industry; electronic appliances. The book provides a wide idea to readers about the usage of appropriate raw material and the treatment involved in the processing of raw material to final produce, safety, uses and properties of raw material involved in the processes. This book concisely presents the core principles and varied details involved in processing of ferroalloys.

The work includes detailed coverage of the major products like ferroaluminium, ferrosilicon, ferronickel, ferromolybdenum, ferrotungsten, ferrovandium, ferromanganese and lesser known minor ferroalloys. Progress in thermodynamics and physico-chemical factors in ferroalloy production has developed rapidly during the past twenty-five years or so. The book presents the principles and current knowledge of processes in the production of various ferroalloys.

The production of a particular ferroalloy involves a number of processes to be followed in order to give the alloy desired physical and mechanical properties. The slight difference in the temperature or heating or composition can lead to entirely different alloy with different properties. This book is not only confined to the different processes followed in the production of ferroalloys but also describes the processes used and other information related to product, which are necessary for the manufacturer's knowledge.

Also, the book gives the reader appropriate knowledge regarding the selection the best of available raw materials.



# TABLE OF CONTENTS

## 1. INTRODUCTION

Theory

Terminology

Interstitial Alloy

Classification of Alloys

## 2. FERROALLOYS

Ferroalloys

Ferro Aluminium

Ferro Boron

Ferro Chromium

Ferro Manganese

Ferro Molybdenum/Molybdic Oxide

Ferro Molybdenum  
Molybdic Oxide  
Ferro Niobium  
Ferro Phosphorus  
Ferro Selenium  
Ferro Silicon  
Ferro Silico Manganese  
Ferro Silicon Magnesium  
Ferro Silicon Zirconium  
Ferrous Sulphide  
Ferro Titanium  
Ferro Vanadium  
Calcium Silicon Manganese  
Calcium Silicon  
Ferro Tungsten  
Iron

### **3. PRODUCTION OF FERROALLOYS**

Primary Processes

Secondary Processes

Applied Processes and Techniques

Ferro-chrome

Raw Materials

Pre-treatment Techniques

Production of Ferro-chrome and Silico-chromium

High-carbon Ferro-chrome

### **4. PRODUCTION OF FERRO MANGANESE**

Raw Materials

Pre-treatment Techniques

Production of Ferro-manganese and Silico-manganese

High-carbon Ferro-manganese

Medium-carbon Ferro-manganese

Low-carbon Ferro-manganese

Silico-manganese

Types of Ferromanganese

Production of Ferromanganese

Production of High Carbon Ferromanganese

Blast Furnace Production

Electric Furnace Production

High Manganese Slag Practice

Discard Slag Practice

Production of Medium-Carbon Ferromanganese

Silicothermic Production of Medium-Carbon Ferro-  
manganese

Production of Medium-Carbon Ferromanganese by  
Oxygen Refining of High-Carbon Ferromanganese

Production of Low-Carbon Ferromanganese  
Thermodynamics of Reduction of Manganese Oxides  
High Carbon Ferromanganese Slags  
Refining of Ferro Manganese  
Introduction  
The Sintering Pilot Facility  
Preparation of the Sinter Mix  
Sintering  
Characterization  
Performances  
Eramet Research Mn Alloys Smelting Pilots  
Background  
Pilot Campaign Approach  
Transfer of the Pilot Results to the Plants  
The New Pyrometallurgy Piloting Facility

Constraints and Stakes for the New Facility  
Definition of the Power Supply Characteristics  
Design of the New Power Supply  
Design of the Furnace  
Furnace Diameter  
Furnace Height  
Side Wall Furnace Lining  
Hearth Lining and Bottom Electrode

## **5. PRODUCTION OF FERRO MOLYBDENUM**

Production of Ferro-molybdenum  
Raw Materials  
Carbo-thermic Production of Ferro-molybdenum  
Metallo-thermic Production of Ferro-molybdenum

## **6. PRODUCTION OF FERRO NIOBIUM**

Introduction

Basic Technology of FeNb Manufacturing

The Evolution of Ferro-niobium Manufacturing

Recent Developments in Ferro-niobium Manufacturing

Pyrometallurgical Refining of Concentrate

Sintering

Electric Arc Furnace Smelting

Ferro-Niobium Production

Crushirm and Packaging

Future Developments in Ferro-niobium Manufacturing

## **7. PRODUCTION OF FERRO BORON**

Ferro-niobium

Production of Ferroalloys from Secondary Raw Material

Raw Material and Raw Material Preparation

## 8. PRODUCTION OF FERRO TITANIUM

Transferred-arc Plasma Furnaces

The Reduction of  $TiO_2$

Enthalpy Considerations

Constitution of the Charge

Choice of Raw Material

Reasons for the Choice of a d.c. Transferred-arc Plasma Furnace

Small-scale Batch Tests in a 50 kVA Water-cooled Furnace

Equipment and Procedures

Objectives of the Experimental Work

Interpretation of Results of the Small-scale Tests

Large-scale Continuous Tests

Further Experimental Work



Melting Point of the Alloy  
The Addition of Iron to the Charge  
Further Furnace Modifications  
Small-scale Sealed Furnace

## **9. PRODUCTION OF FERRO TUNGSTEN**

Production of Ferro-tungsten and Tungsten Melting Base  
Tungsten Melting Base (TMB)  
Ferro-titanium

## **10. PRODUCTION PROCESS OF FERRO SILICON**

Raw Materials  
Production of Ferro-silicon, Silicon Metal and Silico-calcium  
Ferro-manganese and Manganese Alloys

# Refining of Ferro-silicon

Introduction

Processes for the Refining of Ferro-silicon

Solid/Liquid Oxide Method

Oxidising Treatment with Gaseous Oxygen/Enriched Air

Refining with Chlorine Gas

Purification by Carbon Dioxide Injection Method

Typical Results from Studies on the Refining of-Ferrosilicon  
Carried Out at NML

The Chlorine Donor Method

The Carbon Dioxide Injection Method

The Oxygen Injection Method

Conclusions

# Ferro Silicon Operation at IMFA-A Critical Analysis

Introduction

Quality Norms of Raw Materials at IMFA

Quality Deviations Experienced By IMFA

Ferro Silicon Process Description

Formation of Slags in Ferro Silicon

Types of Slag

Characteristics of Different Kinds of Slags

Incompletely converted charge (Slagging)

SiC with Si at the Bottom

Crusts of Sintered Charge Materials in the Upper Parts- of the Furnace

Description of the Furnace

Operating conditions of the Furnace

Problems in the Furnace  
Observations on the Deteriorating Conditions  
Introduction of Lime Stone in the Burden  
Variation in the Slag Properties  
Operating Data  
Improvements in the Furnace Performance  
Comparison of Output Alloy Analysis  
Detrimental Effects of CaO in the Burden Charge  
Overcoming the Problem of Alloy Disintegration  
Remarks and Conclusion  
Controlled solidification of Ferrosilicon  
Introduction  
Experimental Work  
Equipment

Casting  
Investigation  
Results and Discussion  
Primary Silicon Grains  
Eutectic  
Distribution of Aluminium and Calcium  
Cracking  
Porosity  
Conclusions

## **11. PRODUCTION OF FERRO NICKEL**

Raw Materials

Production of Ferro-Nickel from Primary Raw Material

Production of Ferro-Nickel from Secondary Raw Material

# "Ferronickel Ladle Furnace Refining Process"

Introduction

Process Description

Equipment

Process Theory

Oxidation

Desulfurization

Development

Oxidation

Desulfurization

Observation

Conclusions

Design of a Modern Large Capacity FeNi Smelting Plant

History, Applications and Trends

Experiences in FeNi-Smelting and Rectangular Furnaces  
General Trends in the FeNi-production; Industry- Demand  
Design Principles of Large Scale FeNi-smelters  
Calcine Transport System  
Submerged Arc Furnace (SAF)  
Principle of Submerged Arc Furnaces  
Design Principle of a Large-Scale Rectangular FeNi-smelter  
Process and Furnace Dimensioning  
3-D Fluid Dynamic Modelling  
Control and Operation  
Furnace Integrity and Cooling  
Further Application of Side Wall Copper Cooling for-  
Rectangular Furnace

Additional Technological Highlights

SMS DEMAG Tapping Machines

Off-gas System

Plant Start Up

Refining of FeNi

Conclusions and Outlook

## **12. PRODUCTION PROCESS OF FERRO CHROME**

Medium-Carbon Ferro-Chrome

Low-Carbon Ferro-Chrome

Silico-Chromium

Ferro-Silicon and Silicon Alloys

Various Techniques to Produce Low Carbon Ferrochrome

Introduction

Problems of Carbon



Decarburization

Decarburization Techniques

Conventional Techniques

Refining of Ferrochrome by Chromium Ore

Refining of Ferrochrome by Blowing Oxygen

Refining of Ferrochrome with the Presence of Silica

Silicothermic Process for the Production of Low Carbon-  
Ferrochrome

Production of Carbon Free Ferrochrome by- Aluminothermic  
Method

Non Conventional Techniques

Decarburization of Solid Ferrochrome

Decarburization using Oxidizing Gas Mixture

Production of Low Carbon Ferrochrome from Chromite- Ore

Khalafala's Method

Other Methods

Conclusion

Modern Practices of Post Taphole Operation in Ferro Chrome  
Production and its Advantages

Introduction

Mechanized Flow Sheet for Handling High Carbon Ferro  
Chrome Metal 62000 T/Y and Corresponding Slag

Post Taphole Concept

Taphole Installation

Conventional and Freeze Lining Concept

Taphole Configuration

Taphole Lining

Taphole Operation

Temperature Monitor and Control

Important Aspect for Effective Taphole Operation

Movable Tapping Platform

Receptacles

Skimming System

Casting, Crushing, Screening & Handling of Finished Product

Liquid Slag Handling and Disposal

Granulation Process

Recovery of Entrapped Metal from the Slag

### **13. PRODUCTION OF FERROALLOY FROM SECONDARY RAW MATERIALS**

Raw Material and Raw Material Preparation

Preprocessing

Mixing and Drying (Plasma Dust Process only)

Submerged arc Furnace Process

Plasmadust Process

# 14. PRODUCTION TECHNIQUES OF FERROALLOYS

General

Process Description

Submerged Electric Arc Process

Exothermic (Metallothermic) Process

Electrolytic Processes

Emissions and Controls

Aluminothermic Reduction of Oxides with Liquid Start

Description

Innovative Aspect and Main Advantages

Areas of Application

Atomisation of Ferroalloys

The Atomisation Process

Why Atomise (or Granulate)?

To Produce a Saleable, Dust-free Brittle Product

To Produce a Small-sized Ductile Product

To Produce a Reactive Intermediate Product

To Produce a "Rapidly Solidified" Product

To Produce Special Powder Products

Atomisation Processes

Water Atomisation

Gas/Air Atomisation

Centrifugal Atomisation

Atomised Products and Their Markets

Ferrosilicon 15% Dense Medium

Ferrosilicon 45% for the Welding Industry

Ferromanganese for the Welding Industry

Injectables

Higher Melting Alloys

Silicon

[www.entrepreneurindia.co](http://www.entrepreneurindia.co)



Process Selection

The Improvements to Copper Casting Machine for-Ferroalloys

Brief Description of Casting Machine

Artificial Vision System

Monitoring of Main Parameters of the Casting

New Improvements of the Casting Machine

Advantages of the Casting Machine

From the Metal Quality Point of View

From the Economical Point of View

Application of Fluid Bed in Ferroalloy Industry

Introduction

Particle Characterization and Flow Regimes

Fluidized Beds in the Ferroalloy Industry

Ferrochromium Production

Ferronickel Production  
Ferromanganese Production  
Conclusions  
Low Cost Ferroalloy Extraction in DC-ARC Furnace at  
Middleburg Ferrochrome  
Introduction  
The Process Principle of Ferroalloy Recovery  
Description of Electrical System in Place  
Designing the Electrical System According the Process'  
Need  
Keeping the Arc under Control  
Advantage of the DC-arc for Ferroalloy Recovery  
The Furnace' Conductive Bottom  
The Merits of the DC-arc

Optimized Furnace Design  
Refractory Lifetime and General Maintenance  
Power Quality Considerations  
System Overview  
What is Flicker?  
Flicker Calculation and Measurements  
Harmonics  
Power Factor  
DC Reactor Size  
Flicker Mitigation  
Production Increase  
Thermodynamics Applied to Ferroalloys Smelting  
Introduction  
Thermodynamic Data



Chromium

Titanium

Niobium

Vanadium

Thermodynamic Slag Models and Computer Software

Regular Solution Models

Sublattice Models

Quasi-chemical Models

Other Models

Optical Basicity

Industrial Applications

Dephosphorization of Ferromanganese Alloys

Effect of Slag Composition

Effect of Ferroalloy Composition

Effect of Temperature  
Dephosphorization under Reducing Conditions  
Titanium Behavior Description in Silico-manganese- Alloys  
Thermodynamic Modeling  
Industrial Application  
Conclusions  
Techno Economics of Recovering Ferroalloys from Dust- and  
Slag  
Introduction  
Technology  
Metal Recovery from Slags  
Metal Separation  
Metal Fines Remelting/Refining  
Metal Recovery from EAF Dust

Pyrometallurgical Processes

Carbon Steel Dusts

Stainless Steel Dusts

Conclusion

Atomisation of Ferroalloys

The Atomisation Process

Why Atomise (or Granulate)?

To Produce a Saleable, Dust-free Brittle Product

To Produce a Small-sized Ductile Product

To Produce a Reactive Intermediate Product

To Produce a "Rapidly Solidified" Product

To Produce Special Powder Products

Atomisation Processes

Water Atomisation

Gas/Air Atomisation

Centrifugal Atomisation

Atomised Products and Their Markets

Ferrosilicon 15% Dense Medium

Ferrosilicon 45% for the Welding Industry

Ferromanganese for the Welding Industry

Injectables

Higher Melting Alloys

Silicon

Some considerations of future developments in ferroalloy furnaces

Introduction

Present Constraints on the Scale up of Submerged-arc Furnaces

Scale up of the Electrical Circuit

Scale up of the Electrodes

The Supply of Electrical Energy

The Smart Grid

Some Possible Ways for the Ferroalloy Industry to- Adapt to Changes

Submerged-arc Furnaces

Plasma Furnaces

Constraints on Electrodes

Swinging the Load

A Larger Furnace

Conclusions

SHS-Technology of Ferroalloys Nitriding

Introduction

Ferrosilicon Nitride Synthesis

Combustion Temperature

Filtration Combustion

The Phase Composition and the Structure of the- Products

The Industrial Production

Conclusions

Changing Requirements of Ferroalloys for Flat Products

Introduction

Manganese (MN) Ferroalloys

Vanadium (V) Ferroalloy

Other Ferroalloys

Ti Sponge & Low Al Fe-Ti

Fe-Al lump

Fe-Nb lump

Plasma Technology in Ferroalloy Processing

Introduction

Plasma - A Basic Definition

Plasma Furnaces for Ferroalloys Smelting

Process Chemistry Consideratio

Thermodynamics  
Kinetics and Mechanisms  
Slag Chemistry  
Energy Related Issues  
Power Input and Furnace Type  
Energy Requirement and Distribution  
Energy Efficiency  
Advantages over Conventional Process  
Relevance in the Indian Context  
Application of Magnesia Ramming Material in Ferroalloy -  
Refining Furnace  
Introduction  
Development of Ramming Material  
Characteristics of Ramming Material in Ferroalloy- Furnace

High Smelting Temperature  
Good Sintering Property  
Homogeneous and Rational Structure  
Mineral Compositions and Effect of C2F  
Mineral Composition  
The Effect of C2F  
Furnace Dissection Analysis  
Analyses of Erosion Mechanism of Furnace Bottom  
Conclusions

## **15. POLLUTION CONTROL IN FERROALLOY PRODUCTION**

Introduction  
Pollution in Ferroalloys Production  
Assessment of Pollution



Selection of a Pollution Control Device  
Equipments Employed for Pollution Control in Ferroalloy-  
Production  
Process of Pollution Control in Ferroalloys Production  
Illustrations of Stack emissions from a Few Ferroalloy- Plants  
Emissions of Particulates and Dust from Ferroalloy Furnaces  
Illustrations of Pollution Control Systems in Ferroalloys-  
Production  
Two Stage Venturi Scrubbing System for Air Pollution-  
Control from Closed Ferroalloy Furnace  
Conclusions and Remarks

***VISIT US AT***

[www.entrepreneurindia.co](http://www.entrepreneurindia.co)



**TAKE A LOOK AT NIIR PROJECT CONSULTANCY  
SERVICES ON #STREET VIEW**

<https://goo.gl/VstWkd>

[www.niir.org](http://www.niir.org)

[www.entrepreneurindia.co](http://www.entrepreneurindia.co)



# ***NIIR PROJECT CONSULTANCY SERVICES***

**AN ISO 9001:2008 COMPANY**

[www.niir.org](http://www.niir.org)

[www.entrepreneurindia.co](http://www.entrepreneurindia.co)



# WHO ARE WE?

- One of the leading reliable names in industrial world for providing the most comprehensive technical consulting services
- We adopt a systematic approach to provide the strong fundamental support needed for the effective delivery of services to our Clients' in India & abroad

# WHAT DO WE OFFER?

- Project Identification
- Detailed Project Reports/Pre-feasibility Reports
- Market Research Reports
- Technology Books and Directory
- Databases on CD-ROM
- Laboratory Testing Services
- Turnkey Project Consultancy/Solutions
- Entrepreneur India (An Industrial Monthly Journal)

# HOW ARE WE DIFFERENT ?

- We have two decades long experience in project consultancy and market research field
- We empower our customers with the prerequisite know-how to take sound business decisions
- We help catalyze business growth by providing distinctive and profound market analysis
- We serve a wide array of customers , from individual entrepreneurs to Corporations and Foreign Investors
- We use authentic & reliable sources to ensure business precision

# OUR APPROACH

**Requirement collection**

**Thorough analysis of the project**

**Economic feasibility study of the Project**

**Market potential survey/research**

**Report Compilation**



# WHO DO WE SERVE?

- Public-sector Companies
- Corporates
- Government Undertakings
- Individual Entrepreneurs
- NRI's
- Foreign Investors
- Non-profit Organizations, NBFC's
- Educational Institutions
- Embassies & Consulates
- Consultancies
- Industry / trade associations

# SECTORS WE COVER

- Ayurvedic And Herbal Medicines, Herbal Cosmetics
- Alcoholic And Non Alcoholic Beverages, Drinks
- Adhesives, Industrial Adhesive, Sealants, Glues, Gum & Resin
- Activated Carbon & Activated Charcoal
- Aluminium And Aluminium Extrusion Profiles & Sections,
- Bio-fertilizers And Biotechnology
- Breakfast Snacks And Cereal Food
- Bicycle Tyres & Tubes, Bicycle Parts, Bicycle Assembling

# SECTORS WE COVER *CONT...*

- Bamboo And Cane Based Projects
- Building Materials And Construction Projects
- Biodegradable & Bioplastic Based Projects
- Chemicals (Organic And Inorganic)
- Confectionery, Bakery/Baking And Other Food
- Cereal Processing
- Coconut And Coconut Based Products
- Cold Storage For Fruits & Vegetables
- Coal & Coal Byproduct

# SECTORS WE COVER *CONT...*

- Copper & Copper Based Projects
- Dairy/Milk Processing
- Disinfectants, Pesticides, Insecticides, Mosquito Repellents,
- Electrical, Electronic And Computer based Projects
- Essential Oils, Oils & Fats And Allied
- Engineering Goods
- Fibre Glass & Float Glass
- Fast Moving Consumer Goods
- Food, Bakery, Agro Processing

# SECTORS WE COVER *CONT...*

- Fruits & Vegetables Processing
- Ferro Alloys Based Projects
- Fertilizers & Biofertilizers
- Ginger & Ginger Based Projects
- Herbs And Medicinal Cultivation And Jatropha (Biofuel)
- Hotel & Hospitality Projects
- Hospital Based Projects
- Herbal Based Projects
- Inks, Stationery And Export Industries

## SECTORS WE COVER *CONT...*

- Infrastructure Projects
- Jute & Jute Based Products
- Leather And Leather Based Projects
- Leisure & Entertainment Based Projects
- Livestock Farming Of Birds & Animals
- Minerals And Minerals
- Maize Processing(Wet Milling) & Maize Based Projects
- Medical Plastics, Disposables Plastic Syringe, Blood Bags
- Organic Farming, Neem Products Etc.

[www.niir.org](http://www.niir.org)

[www.entrepreneurindia.co](http://www.entrepreneurindia.co)



# SECTORS WE COVER *CONT...*

- Paints, Pigments, Varnish & Lacquer
- Paper And Paper Board, Paper Recycling Projects
- Printing Inks
- Packaging Based Projects
- Perfumes, Cosmetics And Flavours
- Power Generation Based Projects & Renewable Energy Based Projects
- Pharmaceuticals And Drugs
- Plantations, Farming And Cultivations
- Plastic Film, Plastic Waste And Plastic Compounds
- Plastic, PVC, PET, HDPE, LDPE Etc.

# SECTORS WE COVER *CONT...*

- Potato And Potato Based Projects
- Printing And Packaging
- Real Estate, Leisure And Hospitality
- Rubber And Rubber Products
- Soaps And Detergents
- Stationary Products
- Spices And Snacks Food
- Steel & Steel Products
- Textile Auxiliary And Chemicals



# SECTORS WE COVER *CONT...*

- Township & Residential Complex
- Textiles And Readymade Garments
- Waste Management & Recycling
- Wood & Wood Products
- Water Industry(Packaged Drinking Water & Mineral Water)
- Wire & Cable

## **Niir Project Consultancy Services**

**106-E, Kamla Nagar, New Delhi-110007, India.**

**Email: [npcs.india@gmail.com](mailto:npcs.india@gmail.com), [info@niir.org](mailto:info@niir.org)**

**Tel: +91-11-23843955, 23845654, 23845886**

**Mobile: +91-9811043595**

**Fax: +91-11-23841561**

**Website :**

**[www.niir.org](http://www.niir.org)**

**[www.entrepreneurindia.co](http://www.entrepreneurindia.co)**

**Take a look at NIIR PROJECT CONSULTANCY SERVICES on #StreetView**

**<https://goo.gl/VstWkd>**

[www.niir.org](http://www.niir.org)

[www.entrepreneurindia.co](http://www.entrepreneurindia.co)



# Follow Us



➤ <https://www.linkedin.com/company/niir-project-consultancy-services>



➤ <https://www.facebook.com/NIIR.ORG>



➤ <https://www.youtube.com/user/NIIRproject>



➤ <https://plus.google.com/+NIIRPROJECTCONSULTANCYSERVICESNewDelhi/posts>



➤ [https://twitter.com/npcs\\_in](https://twitter.com/npcs_in)



➤ <https://www.pinterest.com/npcsindia/>



**THANK YOU!!!**

**For more information, visit us at:**

**[www.niir.org](http://www.niir.org)**

**[www.entrepreneurindia.co](http://www.entrepreneurindia.co)**

[www.niir.org](http://www.niir.org)

[www.entrepreneurindia.co](http://www.entrepreneurindia.co)