

Comparative Analysis of Security Features in Banknotes Across Various Global Economies Using VSC®-8000/HS.

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Abstract

Background: Banknote counterfeiting is a serious issue. Every government adds various security elements to its banknotes to avoid forgery. The security measures inducted in the banknotes reduce the likelihood of counterfeiting. These are the unique elements that are incorporated during the production process. Paper quality, intaglio printing, watermarks, security threads, latent images, etc. are some of these unique properties. Every nation has a unique set of security characteristics. In the year 2016 India demonetized and recalled all of its highest denomination bank notes (Rs. 1000 and Rs. 500) in order to cease counterfeiting. Thereafter, there has been incorporation of various security features in the current Mahatma Gandhi series to make the currency stand out with other international currencies, in order to reduce the chances of forgery as per the sections 489A-489E of Indian Penal Code, 1872.

Methods: Banknote samples were analyzed using the non-destructive Video Spectral Comparator 8000 (VSC®-8000/HS) by foster+freeman®. Each sample was placed in the live-camera unit with high-resolution 12-megapixel camera forming the part of Super Resolution Imaging (SRI) system. Front and back pictures of the banknotes were taken in white light. The samples were then examined under various illumination settings (Spot Light, Oblique Light, Transmitted Light, UV-light, and Infrared light) for both sides. Security features like Microprinting, Micro texting, Guilloche Pattern, OVI, Watermarks, etc., were studied.

Results: In the current research paper, the security characteristics of the banknotes of ten different countries are compared utilizing VSC®-8000/HS. Analysis reveals Thai Baht with the most security features, followed by Vietnamese Dong, Czech Koruna, Indian Rupees, and others. Notably, Indian banknotes stand out due to UV features, security thread, latent image, and strategic micro text placement.

Conclusions: This research paper recognizes the importance of security features in various banknotes including the Indian banknotes and also provides some of the recommendations to enhance the quality

and security features in the Indian banknotes.

Keywords: Counterfeiting, Banknote, Intaglio Printing, Watermarks, Microprinting, VSC®-8000/HS.

1. Introduction

A banknote is a piece of paper money that consists of a cardinal bank promissory note to pay someone a certain sum of money on demand (Church & Ferguson, 1998). The cardinal bank differs in each nation; they are in-charge of issuing money for that country. For example, the Reserve Bank of India (India), Federal Reserve System (USA), Bank of Thailand (Thailand), European Central Bank (For all European countries- Spain, France, Italy, etc.) and Central Bank of UAE (UAE) etc.

The most significant issue with the new-age currency is maintaining banknotes with up-to-date security features to prevent their counterfeiting. Currency counterfeiting is the imitation of banknotes with the purpose to defraud. The illicit practice of counterfeiting cash has been around since the invention of money (Church & Ferguson, 1998). Recent advancements in digital technology and photography techniques, as well as the availability of low-cost instruments, has simplified the production of counterfeit money, posing a severe threat to national financial systems, banking institutions and clients worldwide. To prevent money from being counterfeited, each country updates its currency on a regular basis by adding technical security features to its banknotes. These security features are of two types; those which can be seen with the naked eye and others that require the use of equipment such as a magnifying glass, an ultraviolet lamp, an infra-red viewer, etc. (Deshpande, 2018).

The most common security features that are seen in most of the banknotes are as follows:

1. Paper quality

Banknotes are not made with the type of paper one may use in their everyday lives. Special paper types are used to provide banknotes with a longer shelf-life and make it difficult to counterfeit. Today, many varieties of new polymers are also being used, since they have a longer life than the typical paper notes and making them resistant towards fire and water or any physical/mechanical damage (Kanwal et al., 2015).

2. Security thread

Security threads are a popular and one of the most secure features, but are quite difficult to create without the use of any specialized instrument or equipment. These threads are woven into the paper at an early stage during the manufacturing of banknotes (Kanwal et al., 2015).. Internal security threads and diving security threads are the two most common forms of security threads. Internal security threads are contained inside the sheet of paper, and these threads may be solid or translucent, with certain micro-inscriptions. Metal and plastics both may be utilized (Kumar et al., 2020). The diving security threads are often made of foil (aluminum or silver), and they include written text that is visible when seen via light source.

3. Intaglio printing

This is another security feature that is incorporated in some of the current banknotes. The word 'intaglio' means 'raised.' The picture is carved into the surface using this method. It is created by applying around sixty layers of color to the same spot on the banknote. The letter or picture gets volume as a result of this layering, and we can feel it by touching it with our fingertips (Jain et al., 2022, Ms, P. 2017).

4. Ultra- violet feature

This is the most recent security feature applied to current banknotes. Because of the fluorescent paint or dyes used in the manufacturing process. The specific picture or denomination on the banknotes illuminates when exposed to UV light (Jain et al., 2022).

5. Micro Texts or Micro lettering

Micro Texts are incredibly small texts that cannot be read with the naked eye. To avoid counterfeiting, they are concealed in many portions of a banknote, such as near faces, numbers, and so on (Jain et al., 2022).

6. Holograms

Holograms are very difficult to forge since they are copied from the primary hologram, which requires expensive, specialized, and technologically innovative equipment. They are implanted using a specific procedure similar to hot-stamping foil (Jain et al., 2022).

7. Anti-copying feature

Also known as Omron Rings. These are certain lines or embellishments that are put onto banknotes using unique software and technology that makes it impossible to copy. Thus, also known as anti-copying/ anti-photocopying feature (Kanwal et al., 2015).

8. Watermarks

Watermarks are the most well-known security feature of any paper currency. A watermark may be a picture or pattern. When a watermark is exposed to light, it looks brighter or darker than the surrounding region. It is printed during the production process by employing a water-coated metal stamp (Jain et al., 2022).

9. Infra-red feature

This is a relatively new security feature in banknotes. At the moment, only few currencies use this feature, it can be comparable to UV illumination seen in the currencies. In this, special types of dyes or inks are used, which when exposed to an IR source either gives a glowing appearance or some of the features vanish like bank name, logo, design or other general appearance features (Ms, P. 2017).

10. Color changing ink

Also referred to as Optically Variable Ink (OVI). This is a unique effect where the color of the impression varies depending on the angle from which it is seen. When the impression is examined, it reveals a raised polygonal shape with one color on the topmost side and a different color on the other sides (Ms, P. 2017).

11. Denomination markings

This is the most used security feature. It is a huge number pattern inscribed numerous times on a banknote in various areas. The denomination signs are seen repeatedly in a variety of forms, such as backdrops, microtexts, etc. to avoid counterfeiting (Ms, P. 2017).

12. Serial numbers

The numbers on banknotes are related to security aspects. The numbers on the banknotes are unique because each banknote has a unique number that is never repeated (Ms, P. 2017).

13. Portraits

Portraits can be seen on the majority of the currencies. They seem to be complicated because of the existence of tiny details in the portrait and this attribute is the most difficult to replicate (Ms, P. 2017, Sahu. et al., 2017).

14. Background decorations

Background decorations are sophisticated and difficult to replicate since they are created by layering numerous layers of ink on top of one another (Sahu. et al., 2017).

15. Braille feature

Every currency in the world has a distinct kind and form of mark. These symbols assist blind persons in identifying types of banknotes by using their fingertips (Kanwal et al., 2015). Also known as braille marks.

2. Methods:

The banknote samples obtained were subjected to the instrumental analysis using Video Spectral Comparator 8000 (VSC®-8000/HS) (foster+freeman®). VSC®-8000/HS (foster+freeman®) is a non-destructive spectral analytical system, in which absorption, reflectance, fluorescence and transmitted spectra can be captured for the various documents (Sahu. et al., 2017). In the present study, various covert security features were observed in the banknotes. Each sample was individually placed into the live-camera unit/ primary unit, and an image of the sample was captured using the Super Resolution Imaging (SRI) system equipment. SRI utilizes a 12-megapixel camera of exceptional precision within its optical system to capture images (Kanwal et al., 2015). First, capturing the front and then the back side, pictures of the banknotes under study were taken using the white light. These samples were then exposed to various illumination settings- Spot Light (SL), Oblique Light (OL), Transmitted light (TL), UV-light (365 nm) and Infrared light (780 nm) in the same manner for both front and back side of the banknotes. After this, other security features were studied one-by-one, like microprinting, micro texting, guilloche pattern, OVI, watermarks, etc. For the purpose of standardization and comparison all the observations under various illumination procedures were viewed under the similar settings. Focus and magnification of the camera system was kept variable for better clarity, observation and capturing of the image in the cases of microprinting and micro texting.

3. Observations:

3.1 Security features of the Euro (€)

The general overview of the security features of Euro were studied for the various available denominations. The 50 Euro denomination banknote was captured from front and backside respectively (Figure. 1 & 2). The security features present on the denomination of 5 Euro banknote were also studied under variety of illuminating conditions namely- Side Light (SL), Oblique Light (OL), Transmitted light (TL), UV-light (365 nm) and Infrared light (780 nm). White light illumination was used to view the security features of the banknote easily seen by the unaided eye (Figure. 3 & 7) such as currency design, color system, serial numbers, motifs, portraits, color panel etc. UV light to decipher the latent features like- UV Ink, security fibers, security thread, hologram, latent image, OVI etc. (Figure. 4 & 8). Transmitted light to decipher the watermark of the queen's portrait and denomination number '5', hologram, security thread etc. were seen (Figure. 5). Infrared light was exposed to view infrared ink and can be seen in the vanishing effect of half of the motif and exposing the other half of it, hologram stripe, denomination number, currency symbol on the glossy stripe, highlighted darkened area of the serial number, etc. (Figure. 6 & 9). Spot light features fluoresces on the front, small circles, large stars and several other areas in the center glows and shines. The € symbol also becomes visible (Figure. 11). Micro-texting is present very significantly in the Euro currency with some areas of the banknote

featuring a series of tiny letters such as the letters and numerals (Euro, 5, signs etc.) are seen very sharp, not blurred.

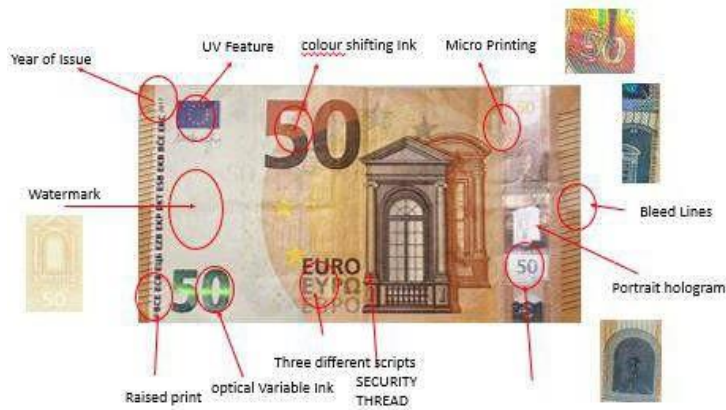


Figure 1-50 Euro-Model with security features (Front)



Figure 2- 50 Euro -Model with security features (Back)



Figure 3-5 Euro under UV (Front)



Figure 4-5 Euro under white light (Front)



VSC3000 User, Default, VSC3000, Serial Number 11029
11/14/16 18:45:2023 Lights=Transmitted, Longpass=VIS, Mag=2.35, White Balance=3720(1) 960(0)
Auto Exposure (Integration=1.0ms, Iris=50%), Brightness=50, Gamma=0.01, Imaged width=126 mm

Figure 5-5-Euro Under IR (Front)



VSC3000 User, Default, VSC3000, Serial Number 11029
11/16/16 18:56:2023 Lights=Fluor, Longpass=VIS, Mag=2.35, White Balance=167(0) 960(0)
Auto Exposure (Integration=1.0ms, Iris=50%), Brightness=50, Gamma=0.01, Imaged width=126 mm

Figure 6- 5 Euro under TL (Front)



VSC3000 User, Default, VSC3000, Serial Number 11029
11/05/16 18:05:2023 Lights=Fluor, Longpass=VIS, Mag=2.35, White Balance=167(0) 960(0)
Auto Exposure (Integration=1.0ms, Iris=50%), Brightness=50, Gamma=0.01, Imaged width=126 mm

Figure 7- 5 Euro under UV light (Back)



VSC3000 User, Default, VSC3000, Serial Number 11029
11/16/16 18:05:2023 Lights=365nm Ultra Violet, Longpass=VIS, Mag=2.35, White Balance=511(0) 511(0)
Auto Exposure (Integration=3000ms, Iris=50%), Brightness=50, Gamma=0.01, Imaged width=126 mm

Figure 8-5 Euro under White light (Back)



Figure 9- 5 Euro Microtexts (Back)

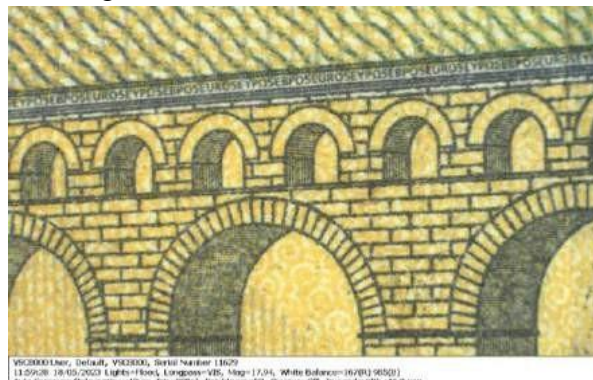


Figure 10- 5 Euro under IR (Back)



Figure 11-5 Euro under Spot Light (Back)

3.2 Security features of the American Dollar (\$):

Security features of various denominations for American currency were observed front and backside respectively. The 50 dollar denomination banknote was studied for covert security features like federal

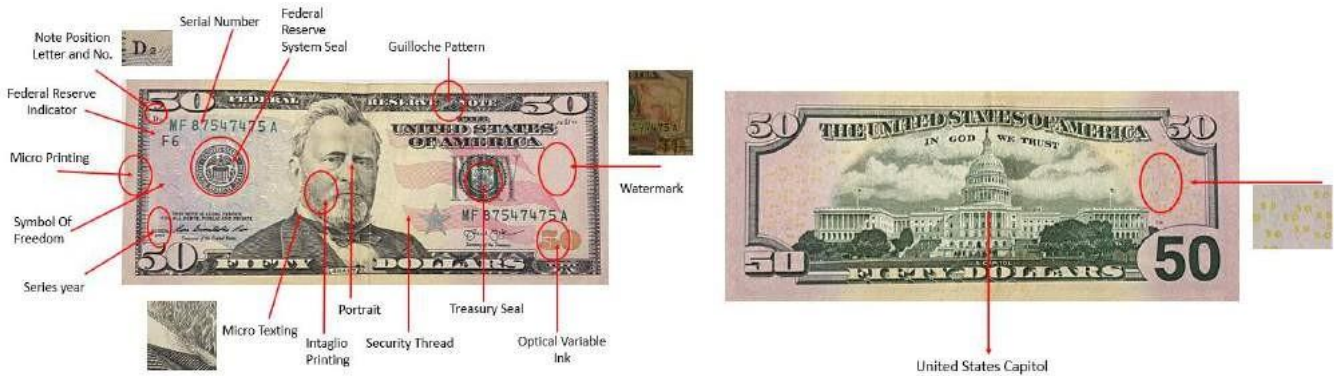


Figure 12- 50 US Dollar with security Features (Back) Figure 13- 50 US Dollar with security Features (Front)

reserve indicator, treasury seal, series, year, symbol of freedom, federal system seal, etc. (Figure. 12 & 13). Security features were observed in the denomination of 5 dollars using side Light (SL), oblique Light (OL), Transmitted light (TL), UV-light (365 nm) and Infrared light (780 nm). Under white light security features like microprinting, micro-texting, security ribbon, optical variable ink, portrait, intaglio printing currency design, color system, serial numbers, and motifs were observed (Figure. 14 & 19). UV light deciphered the latent features like- UV Ink, security fibers, security thread/ ribbon, hologram, latent image, OVI etc. (Figure. 16 & 21) Transmitted light deciphered watermark denomination number ‘5’ on the left side of the note, latent image, hologram, security thread etc. (Figure. 17). Under the Infrared light much was not observed on the front side but the back side of the note seemed to have disappeared off the motif (US capitol building) suggesting the sensitivity of the IR light towards the ink. (Figure. 18 & 22). Spot light features were observed fluorescing on the front, the small circles, the large stars and several other areas like the great seal of the US in the center glows and shines. The dollar bill symbol was also visible under the SL (Figure. 15 & 20). Micro-texting was present very significantly in great deal with some areas of the banknote featuring a series of tiny letters written United States of America, name of all the states (Figure. 23). The letters and numerals (USA, 5, signs, etc.) were observed very sharply.

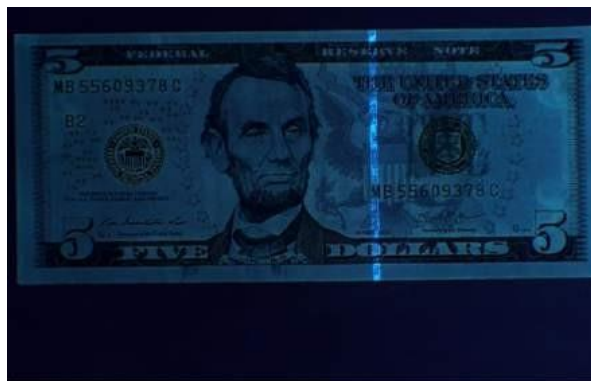


Figure 14-5 US Dollar- Under White Light (Front)



VC20001 User, Default, VC20000, Serial Number 116279
 11:22:52 18.45-29223 Light=Spot, Exposure=475, Magn=1.01, White Balance=5110(5110)
 Auto Exposure (Integration=150ms, Iris=50%), Brightness=50, Gamma=0ff, ImageJ width=158mm

Figure 15- 5 US Dollar- Spot Light (Front)



VC20001 User, Default, VC20000, Serial Number 116279
 11:23:22 18.45-29223 Light=UV, Exposure=475, Magn=1.01, White Balance=5110(5110)
 Auto Exposure (Integration=500ms, Iris=50%), Brightness=50, Gamma=0ff, ImageJ width=158mm

Figure 16-5 US Dollar- UV Features (Front)



VC20001 User, Default, VC20000, Serial Number 116279
 11:23:54 18.45-29223 Light=TL, Exposure=475, Magn=1.01, White Balance=5110(5110)
 Auto Exposure (Integration=5.1ms, Iris=50%), Brightness=50, Gamma=0ff, ImageJ width=158mm

Figure 17- 5 US Dollar- TL



VC20001 User, Default, VC20000, Serial Number 116279
 11:24:10 18.45-29223 Light=IR, Exposure=475, Magn=1.01
 Auto Exposure (Integration=1.3ms, Iris=50%), Brightness=50, Gamma=0ff, ImageJ width=158mm

Figure 18-5 US Dollar- IR Features (Front)



VSC3000 User, Default, VSC2000, Serial Number 11629
11:07:50 18/05/2023 Lights=Flood, Longexps=700, Mag=1.60, White Balance=10710 (9000)
Auto Exposure (Integration=13ms, Iris=50%), Brightness=50, Gamma=0.0, Imaged width=165 mm

Figure 19-5 US Dollar under white light (Back)



VSC3000 User, Default, VSC2000, Serial Number 11629
11:38:04 18/05/2023 Lights=Spot 400-800 (0), Longexps=640, Mag=1.60
Auto Exposure (Integration=330ms, Iris=20%), Brightness=50, Gamma=0.0, Imaged width=165 mm

Figure 20-5 US Dollar- under spot light



VSC3000 User, Default, VSC2000, Serial Number 11629
11:39:25 18/05/2023 Lights=360nm Ultra Violet, Longexps=400, Mag=1.60, White Balance=51400 (51400)
Auto Exposure (Integration=500ms, Iris=50%), Brightness=50, Gamma=0.0, Imaged width=165 mm

Figure 21-5 US Dollar under UV Light



VSC3000 User, Default, VSC2000, Serial Number 11629
11:40:23 18/05/2023 Lights=Flood, Longexps=700, Mag=1.60
Auto Exposure (Integration=13ms, Iris=50%), Brightness=50, Gamma=0.0, Imaged width=165 mm

Figure 22-5 US Dollar under IR Light

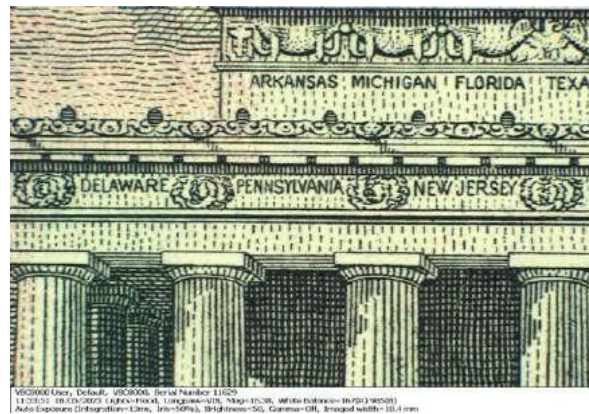


Figure 23-50 US Dollar- Microtexts

3.3 Security features of the Indian Currency: (₹)

The Indian banknote was studied for the denomination of 2000 rupees in order to observe the overall security features present like portrait, watermark, denomination number, serial number, security ribbon, etc. (Figure. 24 and 25). The banknote of 500 rupees was also observed under white light to explore the security features such as see-through register displaying the denominational numeral "500," as well as the latent image of the same numeral, denominational numeral "500" in Devanagari script and features a prominent portrait of Mahatma Gandhi at its center. A color-shifting windowed security thread runs through the note, bearing inscriptions of "RBI" and "500." This thread changes color from green to blue when tilted, providing an easily recognizable and anti-counterfeiting feature. The note's guarantee clause, along with the Governor's signature and the RBI emblem, can be found towards the right of Mahatma Gandhi's portrait. A number panel featuring ascending numerals is situated on the top left and bottom right corners of the note. Additionally, the Ashoka pillar emblem is present on the right side of the note. (Figure. 26 and 31). Micro letters spelling "RBI", "India" and भारत are integrated into the design, adding an additional layer of security (Figure. 36 and 37). When studied under TL watermark of Mahatma Gandhi's portrait and the numeral "500" (in electrotype) are observed in the note's design. (Figure. 27, 32). Under UV light various security threads were observed that fluorescence all over the note, denominational numeral was observed to be printed with rupee ink and features a color-changing (green to blue) symbol of "500" on the bottom right corner along with the serial number giving a mild fluorescent (Figure. 29). Security ribbon providing a strong yellow glow under UV with RBI written in microprint on it (Figure. 34). There were no IR Features found in Indian currency (Figure. 30,35) These various features collectively enhance the security and authenticity of the 500 rupees note, making it difficult to replicate and ensuring its integrity in circulation. The light does not offer such a great display of covert features for the front side of the note (Figure. 27) but the security ribbon seemed to be glowing with inscribed RBI in microprint (Figure. 33).

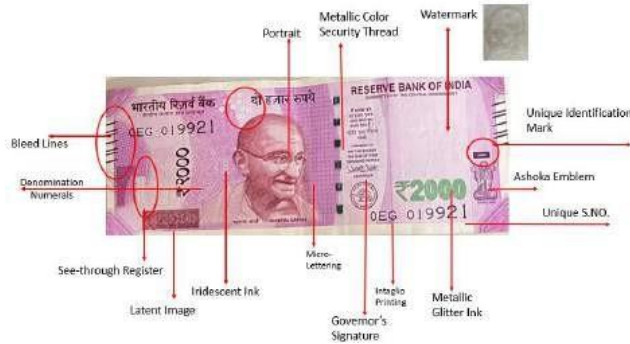


Figure 24-2000 INR with security features (Front)

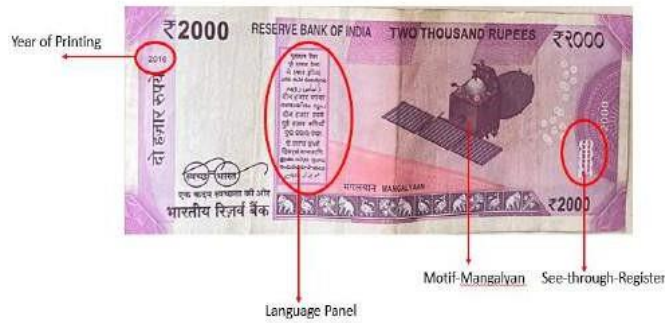


Figure 25-2000 INR with security features (Back)



VIS2000 User, Default, VIS2000, Serial Number 11629
 12:41:52 17/05/2023 Lights=Front, Language=VIS, Mag=1.05, White Balance=16763 (8580)
 Auto Exposure (Integration=12ms, Gain=50%), Brightness=30, Gamma=0.8, Image width=1314 px

Figure 26-500 INR under white light (Front)



VIS2000 User, Default, VIS2000, Serial Number 11629
 12:42:58 17/05/2023 Lights=Transmitted, Language=VIS, Mag=1.05, White Balance=32201 (6090)
 Auto Exposure (Integration=3.1ms, Gain=50%), Brightness=30, Gamma=0.8, Image width=1314 px

Figure 27- 500 INR under TL (Front)



VSC3000 User, Default, VSC3000, Serial Number 11629
12-16:00 17/05/2023 Lights=Spot, Longpass=0, Mag=1.00
Auto Exposure (Integration=500ms, Iris=50%), Brightness=50, Gamma=0.0, Imaged width=134 mm

Figure 28-500 INR under SL (Front)



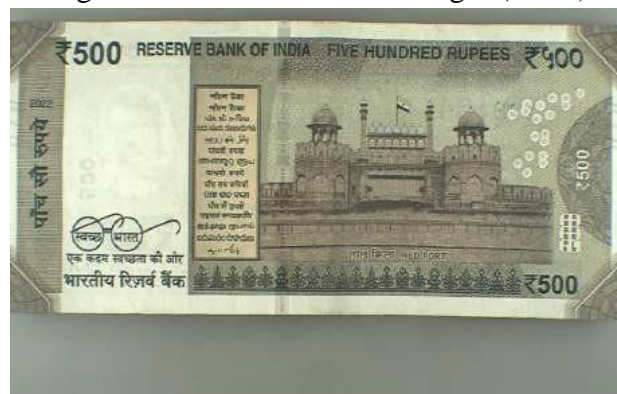
VSC3000 User, Default, VSC3000, Serial Number 11629
12-16:00 17/05/2023 Lights=365nm Ultra Violet, Longpass=0, Mag=1.00, White Balance=31 (P3.51101)
Auto Exposure (Integration=500ms, Iris=50%), Brightness=50, Gamma=0.0, Imaged width=134 mm

Figure 29-500 INR under UV light (Front)



VSC3000 User, Default, VSC3000, Serial Number 11629
12-16:00 17/05/2023 Lights=IR, Longpass=700, Mag=1.00
Auto Exposure (Integration=120ms, Iris=50%), Brightness=50, Gamma=0.0, Imaged width=157 mm

Figure 30- 500 INR under IR light (Front)



VSC3000 User, Default, VSC3000, Serial Number 11629
12-16:05 17/05/2023 Lights=Flash, Longpass=0, Mag=2.05, White Balance=167 (P3.96083)
Auto Exposure (Integration=11ms, Iris=50%), Brightness=50, Gamma=0.0, Imaged width=147 mm

Figure 31- 500 INR under white light (Back)



VSC2000 User, Default, VSC2000, Serial Number 11629
 13/06/20 17:05:26(3) Light=Transmitted, Longpass=IRB, Mag=2.0x, White Balance=3(201) (66/0)
 Auto Exposure (Integration=1.5ms, Iris=50%), Brightness=50, Gamma=0%, Image width=147 mm

Figure 32- 500 INR under TL (Back)



VSC2000 User, Default, VSC2000, Serial Number 11629
 13/06/20 17:05:26(3) Light=Spot 400-815 (6), Longpass=64x, Mag=2.0x
 Auto Exposure (Integration=250ms, Iris=75%), Brightness=50, Gamma=0%, Image width=147 mm

Figure 33- 500 INR under Spot Light (Back)



VSC2000 User, Default, VSC2000, Serial Number 11629
 13/06/20 17:05:26(3) Light=365nm Ultra Violet, Longpass=VIS, Mag=2.0x, White Balance=811(R3)14(0)
 Auto Exposure (Integration=180ms, Iris=50%), Brightness=50, Gamma=0%, Image width=147 mm

Figure 34- 500 INR under UV (Back)



VSC2000 User, Default, VSC2000, Serial Number 11629
 13/06/20 17:05:26(3) Light=IR-850, Longpass=78x, Mag=2.0x
 Auto Exposure (Integration=130ms, Iris=50%), Brightness=50, Gamma=0%, Image width=147 mm

Figure 35- 500 INR under IR (Back)

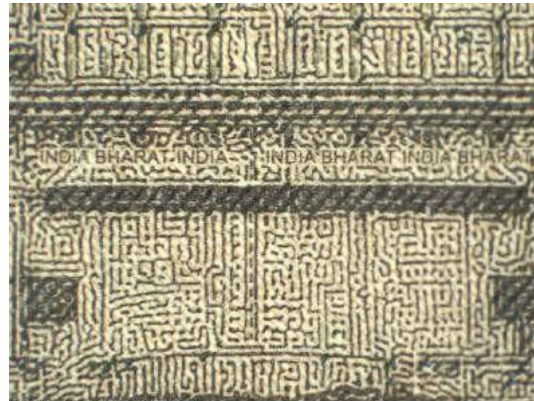


Figure 36- 500 INR Microtexts



Figure 37- 500 INR Microprinting

3.4 Security features of Thai Baht (฿)

The 100 Baht denomination banknote was observed to study the security features present in Thai currency, security features like see through register, bleed lines, metallic glitter ink, security ribbon, denomination mark, etc. (Figure. 38,39). UV features were studied in great detail like the spread of security fibers, glowing denomination numeral, optical variable ink fluorescence along with portrait, serial number and emblem. (Figure. 40,41)



Figure 38- Thai Bhat 100- Security features (Front)



Figure 39- Thai Bhat 100- Security features (Back)



Figure 40- Thai Bhat 100- UV Security features (Front)



Figure 41- Thai Bhat 100- UV Security features (Back)

3.5 Security features of the UAE Dirham (!.)

The 50 Dirham denomination banknote was observed to get a general overview of the overall overt and covert features present in the currency of UAE, security features like hologram transparent window, intaglio printing, logo, serial number, ink, etc. UV features were observed in serial number, latent denomination numeral present in a square box located at the center of the banknote, signature, year of printing etc. (Figure. 44, 45).



Figure 42- 50 Dirham with security features (Front)

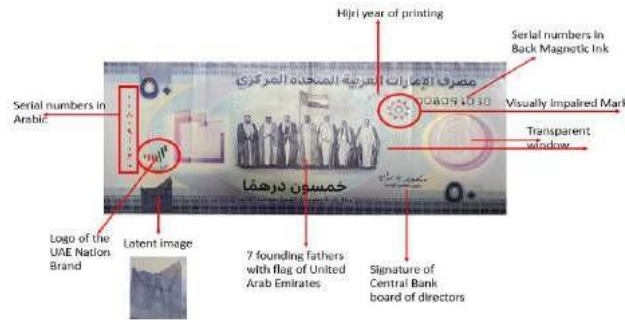


Figure 43- 50 Dirham with security features (Back)

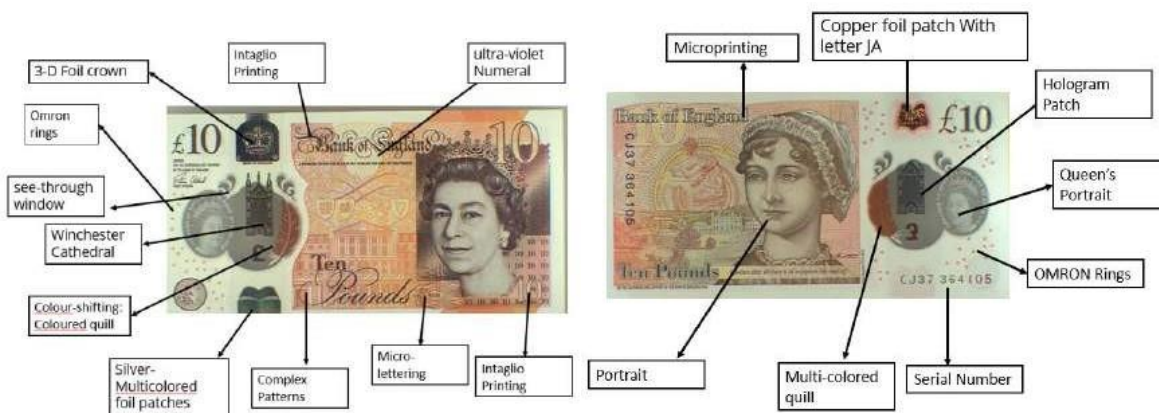


Figure 44- Latent UV Feature in 50 Dh (Back)



Figure 45- Latent UV Feature in 50 Dh (Front)

3.6 Security features of the British Pounds (£)



For

analyzing the British banknote of 10 Pounds denomination was observed and the security features like silver foil stripe, crown, hologram, cathedral window, paper type, etc. were seen (Figure. 46,47). White light was used to observe see through the window, micro printing, omron rings, complex patterns, serial

number etc. (Figure. 48,54). UV light band was used to study the multi-color denomination numeral ‘10’ present at the middle top area of the bank note, color shifting ink to a light-greenish color was seen on the reverse side, which was unique to this banknote only (Figure. 51,57). Spot light was used to observe latent features such as glowing silver foil strip, denomination number along with sign and euro signature. Under the spot light the portrait was observed glowing in the white-grayish color distinctly (Figure. 50,56). IR features were greatly observed like the hologram of the cathedral, queen’s portrait, crown present along the silver foil strip, and half of the queen’s portrait on the right side was displaying the characters and sensitivity towards the IR light (Figure. 52,58). Microtext and Microprinting were distinctly explored in great deal, present in the unusual areas. (Figure.53,59)



Figure 46- 10 Pounds with security features (Front)



Figure 47- 10 Pounds with security features (Back)



Figure 48- 10 Pounds under White Light (Front)



Figure 49- 10 Pounds under TL (Front)



Figure 50- 10 Pounds under Spot Light (Front)



Figure 51- : 10 Pounds under UV Light (Front)



Figure 52- 10 Pounds under IR Light (Front)



Figure 53- 10 Pounds Microtexting



Figure 54- 10 Pounds under White Light (Back)



Figure 55- 10 Pounds under TL (Back)



Figure 56- 10 Pounds under Spot Light (Back)

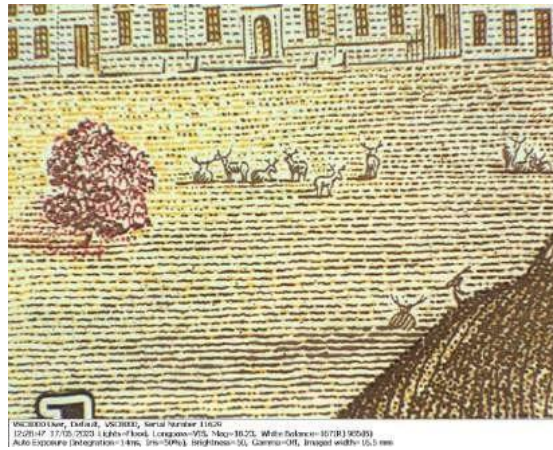


Figure 57- 10 Pounds under UV Light (Back)

Figure 58- 10 Pounds under IR Light (Back)

Figure 59- 10 Pounds Microprinting

3.7 Security features of the Australian Dollar (AUD)

The Australian dollar banknote of denomination 20 was observed for the overall security features like paper type, intaglio printing, denomination number, see through register etc. (Figure. 60,61). White light was used to observe the overt features in depth like micro printing, micro texting, bleed lines, color shifting ink (Figure. 62,68). Spot light was applied to observe the latent and fluorescent features of ink, hologram, micro printing on hologram and watermarks (Figure. 63,69). UV light deciphers the features that interact with the latent features of ink, watermark, optical variable ink, glowing serial number and denomination numeral of 20 AUD. (Figure. 64). In transmitted light the hologram was seen from both the sides (Figure. 65,70). When observed under the IR light multiple covert features were seen like disappearance of the geometric array of the bordered patterns, and see-through register. (Figure. 66,71). Micro-texting and Micro-Printing were also observed (Figure.67)



Figure 60- 20 AUD general security features (Front)



Figure 61-20 AUD general security features (Back)



Figure 62-20 AUD under white Light (Front)



Figure 63- 20 AUD under spot light (Front)



Figure 64-20 AUD under UV light (Front)



Figure 65-20 AUD under TL (Front)



Figure 66-20 AUD under IR light Front

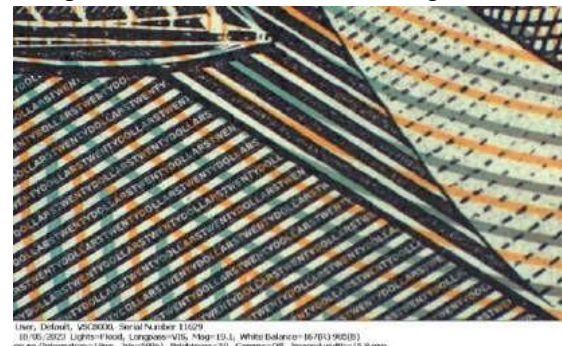


Figure 67-20 AUD Micro texting



VSC3000 User, Default, VSC3000, Serial Number 11629
12/27/23 15:05:2023 Lights=Fluor, Longpass=10, Mag=2.00, White Balance=10790 (9549)
Auto Exposure (Integration=10ms, Iris=50%a, Brightness=50, Gamma=0ff, Image width=148 mm)

Figure 68-20 AUD under White light (Back)



VSC3000 User, Default, VSC3000, Serial Number 11629
12/27/23 15:05:2023 Lights=Spot 900 (450.0), Longpass=615, Mag=2.00
Auto Exposure (Integration=500ms, Iris=70%a, Brightness=50, Gamma=0ff, Image width=148 mm)

Figure 69- 20 AUD under spot light (Back)



VSC3000 User, Default, VSC3000, Serial Number 11629
12/27/23 15:05:2023 Lights=Transmitted, Longpass=418, Mag=2.00, White Balance=32791 (86001)
Auto Exposure (Integration=3.3ms, Iris=50%a, Brightness=50, Gamma=0ff, Image width=148 mm)

Figure 70-20 AUD under TL (Back)



VSC3000 User, Default, VSC3000, Serial Number 11629
12/27/23 15:05:2023 Lights=IR660, Longpass=790, Mag=2.00
Auto Exposure (Integration=8ms, Iris=50%a, Brightness=50, Gamma=0ff, Image width=148 mm)

Figure 71-20 AUD under IR (Back)

3.8 Security features of the Indonesian Rupiah (Rp)

The Indonesian banknote of 50000 Rupiah denomination was observed for the security features like omron rings, see through register, bleed lines, intaglio printing, portrait etc. (Figure. 72,73). White

light was used to observe other overt features present such as ink color, paper type, logo, micro printing, micro texting etc. (Figure. 74,81). Spot light revealed multiple fluorescent features like watermark, glowing map and flowers along with the Omron rings (Figure. 75,82). Multiple UV features were observed in the 50000 Rp with denomination number being present and glowing in multicolor, patterns of flower, flower, latent image, leaves and border of the note (Figure. 76)

Transmitted light illumination was used to observe watermarks on both front and back sides of the currency (Figure. 77,84). Infrared features observed were the emblem of Indonesian rupiah, serial number and half of the god's portrait (Figure.78,85). Microtext, complex colorful geometric patterns, omron rings, and microprinting were also observed (Figure.79,80).



Figure 72-50000 Rp general security Features (Front)



Figure 73-50000 Rp general security Features (Back)

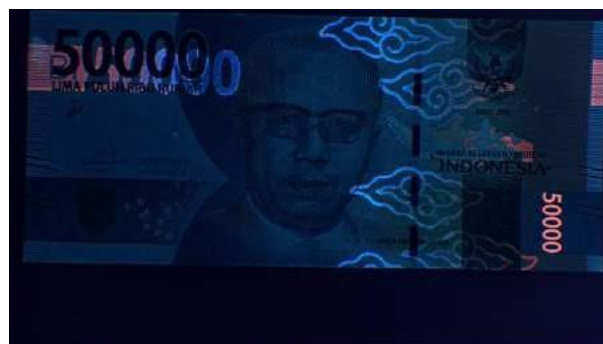


Figure 74-50000 Rp under White light (Front)



VSC3000 User, Default, VSC3000, Serial Number 11629
12/25/20 18:16:2023 Light=Transmitted, Longpass=VIS, Mag=1.89, White Balance=3720U 869RB
Auto Exposure (Integration=3.2ms, Iris=50%), Brightness=50, Gamma=Off, Imaged width=150 mm

Figure 75-50000 Rp under spot light (Front)



Figure 76-50000 Rp under UV light (Front)

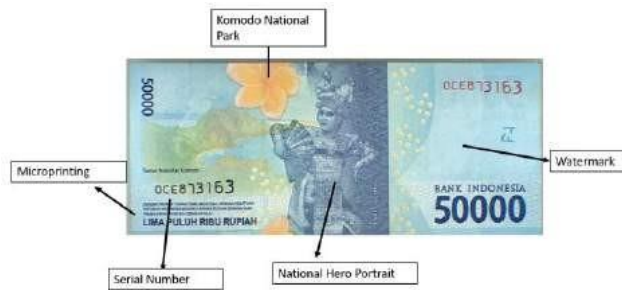


Figure 77-50000 Rp under Transmitted light



VSC3000 User, Default, VSC3000, Serial Number 11629
12/25/22 16:50:0023 Light=Passed, Longpass=IR, Mag=1.89
Auto Exposure (Integration=3.2ms, Iris=50%), Brightness=50, Gamma=Off, Imaged width=150 mm

Figure 78-50000 Rp under IR (Front)



Figure 19-50000 Rp Microtext and Microprint

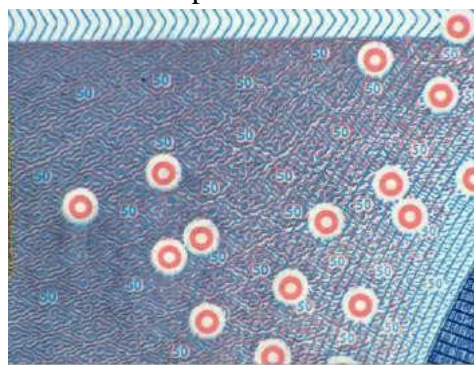


Figure 80-50000 Rp OMRON feature



Figure 81-50000 Rp under White Light (Back)



Figure 82-50000 Rp under spot light (Back)



Figure 83-50000 Rp under UV light (Back)



Figure 84-50000 Rp under TL (Back)



Figure 85-50000 Rp under IR light (Back)

3.9 Security features of the Czech Koruna (Kč)

Overall security features like see through register, omron rings, security ribbon, patterns, etc. were studied for Czech banknotes of 1000 Kč Koruna denomination (Figure.86- Figure.98). White light illumination to observe overt features like micro printing, micro texts, indescnt stripe, offset printing, intaglio printing etc. (Figure.88,97). UV light was applied to study the security fibers and were seen giving bluish, yellowish and greenish like luminescence, multi-colored luminescence in lower and upper part of the banknote, lower part of portrait and part of blind code with blue luminescence, left-side of portrait, and stylized linden leaves in lower left and upper right corners with green luminescence (Figure. 89, 94). Spot light showed the fluorescence nature of security fibers, denomination numeral was

half visible, watermark, patterned array of leaves, visibility of half portrait. Transmitted light focused on the see through register and watermarks. In IR light 1000 Korun was examined resulting in the visibility of half denomination numerals, leaf, security thread, half portrait without head were observed.

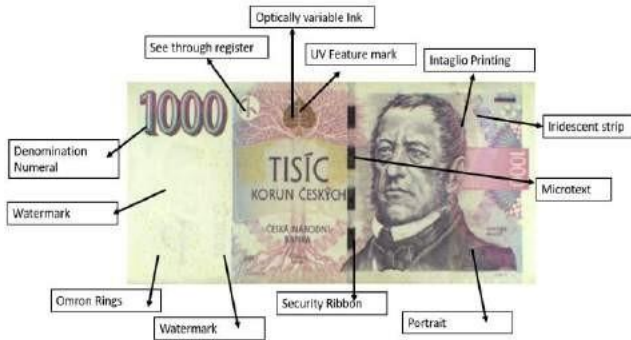


Figure 86-1000 Korun under White light (Front)

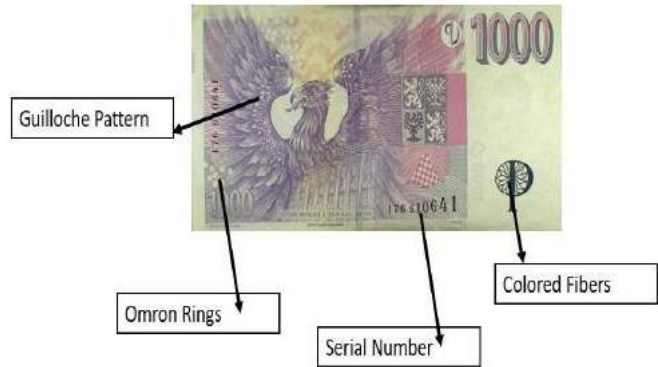


Figure 87-1000 Korun under White



Figure 88-1000 Korun under White light (Front)



Figure 89-1000 Korun under UV light (Front)



Figure 90-1000 Korun under Spot light (Front)



Figure 91-1000 Korun under Transmitted light (Front)



Figure 92 -1000 Korun under IR light (Front)



Figure 97-1000 Korun under White light (Back)security fibers (Back)



Figure 98- 1000 Korun showing OMRON rings (Back)

3.10 Security features of the Vietnamese Dong (đ)

Various security features of Vietnamese Dong were observed (Figure.99-Figure.108). Vietnamese banknotes of 500 denomination were observed for general security features such as color of the note, portrait, serial number, patterns, motif etc. (Figure.99,100). White light was illuminated on the 500 denominations to study the overt features for both front and back side of the note like Complex Patterns, Microprinting, ink color, geometry etc. (Figure. 101, 106). Spot light was illuminated to observe the luminescence of minute security fibers, watermark, fluorescent nature of ink (Figure. 102,107). UV light was shone on the 500 Dong to observe the covert features such as fluorescence of UV sensitive fibers, and ink used for serial number in color red was also seen (Figure.103,108). Transmitted light was used to study the guilloche patterns, watermarks present in the note and portrait features (Figure.104). Portrait present on the note, geometric flowers, denomination number, and logo seemed to disappear due to the sensitivity against the IR light (Figure.104).



Figure 99-Security Features of Vietnam Currency (Front)



USC3000 User, Default, USC3000, Serial Number 116094
 12/31/19 16:05:2023 Lights=Front, Longpass=95%, Midp=20%, White Balance=60/0/10000
 Auto Exposure (Integration=11ms, Gain=5000), ISO/Speed=50, Camera=080, ImageSize=131mm

Figure 100-500 Dong under White Light (Front)



USC3000 User, Default, USC3000, Serial Number 116094
 12/31/19 10:45:2023 Lights=Spot, Midp=80.00, Longpass=60%, Midp=23
 Auto Exposure (Integration=200ms, Gain=1000), ISO/Speed=50, Camera=080, ImageSize=131mm

Figure 101-500 Dong under Spot Light (Front)



Figure 102-500 Dong under UV light (Front)



Figure 103- 500 Dong under TL (Front)



Figure 104-500 Dong under IR (Front)



Figure 205- 500 Dong under White light (Back)



Figure 106-500 Dong under Spot light (Back)



Figure 107-500 Dong under UV light (Back)

Table 1- Various security features in the banknotes under study

Features	€	USD	₹	฿	Dh	£	AUD	Rp	Kč	₫
Intaglio printing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Watermark	✓	✓	✓	✓	✓	+	✓	✓	✓	✓
Spot Light	✓	+	+	✓	+	✓	+	✓	✓	✓
Security Fibers	✓	+	✓	✓	+	+	+	+	✓	✓
Security thread	+	✓	✓	✓	✓	+	+	✓	✓	+
UV features	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Microprinting	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hologram	+	+	+	✓	✓	✓	✓	+	+	✓

Anti-photocopying/Omron Rings	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
OVI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Portrait	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Latent image	+	+	✓	+	✓	+	+	+	✓	+
See-through register	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Denomination mark	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Visual Impaired Feature	✓	✓	✓	✓	✓	+	✓	✓	✓	✓
Material used	cotton	75% cotton + 25% Linen	Cotton	Polymer with special coating	Polymer	Mixed cotton + Polymer	Polymer	cotton	cotton	Polymer
IR-Features	✓	✓	+	✓	✓	✓	✓	✓	✓	✓
Micro texting	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Guilloche Pattern	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

4. Results:

The various covert security features were studied using VSC8000/HS in the banknotes of various countries. It is evident from the Table-1, that Thai Baht has the highest number of security features, followed by Vietnamese Dong, Czech Koruna, Indian Rupees, UAE Dirham, Euro, Indonesian Rupiah, American Dollar, Australian Dollar, and British Pound with the least number of security features. However, the Indian banknotes have features like UV features, security thread, latent image, strategic placement of micro texts which strengthens it and helps in prevention and detection of counterfeiting.

5. Discussion:

The study's findings can be used by bank employees, security personnel, money changers and forensic investigators to identify counterfeit Indian rupee notes. The process is quick, efficient, and user-friendly. Several studies have compared the security features of banknotes from different countries (Mann, Shukla, & Gupta, 2015). The present study focuses on the comparison of 9 different countries with that of India, various currencies have a variety of features preventing their counterfeiting. Some of the features that were reported common were Intaglio-printing, Micro-texting, Micro-printing, UV Features, Watermarks, Guilloche pattern and others (van der Horst et al., 2021). Also, a lot can be done to reduce counterfeiting by adding more security features to the Indian Currency such as: Planchettes, Pole Features, Rainbow Printing, Thermal Ink, and Transparent intaglio disappearing effect TIED Lithograph, Magnetic Ink, Metal Coated Image etc. can improve the quality and uniqueness of authentic banknotes while reducing production costs.

6. Conclusion:

This study article emphasizes and does a comparative analysis of the various security elements that are overt and covert, thus helping in the prevention of the banknotes against counterfeiting. For those involved in currency validation and protection, the distinctions between banknotes from other nations—particularly the unique security features of Indian rupee notes—serve as an invaluable resource. The in-depth examination of counterfeiting deterrents is made possible by the thorough analysis of security characteristics that takes into account numerous nations. Future work might be focused on implementing additional security features in Indian money and determining their viability based on this basis. This has the ability to strengthen security while also advancing banknote design and technology on a global scale.

List of abbreviations:

1. AUD- Australian Dollar
2. D- Vietnamese dong
3. DH- Dirham
4. HS- High Resolution
5. INR- Indian rupee
6. IR- Infrared
7. Kc- Czech Koruna
8. OL- Oblique light
9. OVI- Optical variable Ink
10. RBI- Reserve Bank of India
11. Rp- Indonesian Rupiah
12. SL- Spot light
13. TIED- Transparent intaglio disappearing effect.
14. TL- Transmitted light
15. UAE- United Arab Emirates
16. US- United States
17. USD- United States dollar
18. UV- Ultra-violet
19. VSC- Video Spectral Comparator

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