Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268 (Print copies up to 2016)
e-ISSN: 2395-3454

Vol. 21 | No. 3 | pp. 1333-1340 | 2022

Original Research Paper

https://doi.org/10.46488/NEPT.2022.v21i03.040

Open Access Journal

Bio-medical Waste Remediation by Environmental Safe Gelatin Coated Blood Sample Paper and its Effective Utilization

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 28-02-2022
Revised: 28-03-2022
Accepted: 09-04-2022

Key Words:
Bio-medical waste
Environment issues
Gelatin coating
Blood sampling

ABSTRACT

Sustainability in human development sets exact standards for the management of natural resources, including their extraction, use, and the introduction of waste products into a complex, inventive circuit as a consequence of exploitation. Because of the negative influence that medical waste has on the environment and people, it needs specific handling. Medical waste is increasing in amount all the time and has a wide range of consequences across a wide range of activity domains. This paper discusses various issues of the sustainable management of blood sample bio-medical waste and evaluates the properties of alternative samples which are made of gelatin-coated sample paper. A unique bar-coded paper-based blood sample method has prevented complications during blood tests and is much more environmentally friendly.

INTRODUCTION

A healthy atmosphere is the most important element for living a healthy lifestyle. The waste that is created in various hospitals has a direct or indirect relationship with the human environment in one way or another. If the waste is not collected and disposed of in line with the standards, it has the potential to cause environmental damage. Calis & Arkan (2014) conducted a survey to determine if nursing students were aware of the harm caused by medical waste to the environment and human health.

Its characteristics and content are very diverse in biomedical waste, which covers a wide range of waste generated in a variety of settings such as hospitals, nursing homes, medical research facilities, clinics, and medical stores. Biological waste poses a threat to the health of the general public if it is not adequately controlled. Already, ten distinct forms of waste have been identified as being associated with health hazards. The number of hospitals and nursing homes is expanding in tandem with the increase in the human population, and as a result, the amount of trash being created is increasing as well (Mastorakis et al. 2011). The kind of specialty and the grade of the hospitals have an impact on the quality and amount of waste generated daily, respectively. Furthermore, the location of the hospital will most likely influence the kind and amount of waste generated. A total of more than 30 tons of biological waste is generated daily by hospitals in major metropolitan areas. It is a source of serious worry because the majority of hospitals, particularly those administered by the government, are not adequately maintained (Mathur et al. 2012).

Because it cannot be made harmless before being buried in the ground or disposed of in water, medical waste has been labeled as a source of soil and water pollution. Growing demand for medical services throughout the globe, along with a rise in the usage of disposable medical goods, has contributed to the massive volume of medical waste created. Environmental pollution, unpleasant odor, and the growth and multiplication of insects, rodents, and worms are all consequences of poor medical waste management. It also increases the risk of disease transmission through the use of sharps that have been contaminated with blood, such as typhoid fever, cholera, and hepatitis A (Babanyara et al. 2013).

In the current context of this pandemic, waste management is crucial to the long-term development of mankind. The treatment and disposal of bio-clinical waste generate a large amount of hazardous biomedical waste. Medical waste creation and disposal is a major issue in developing nations with poor sanitation and large populations. Hospitals, clinics, and other medical facilities create hazardous waste and expose patients to potentially fatal infections. Trash management policies should outline how waste should be dealt with at each phase of the waste management process, from creation through treatment. To reduce the risk of health issues spreading, it is critical to raise public awareness via various communication and educational methods. Healthcare waste may include pathogens that might infect hospital patients, healthcare employees, and the general public (Biswapriya et al. 2021).

However, although the COVID-19 pandemic is supposed to have decreased air pollution and environmental-related noise, and has enhanced biodiversity and tourism sites, the effect of people staying at home and taking precautionary measures on waste management has been alarmingly negative. A waste problem seems to be developing as a result of the unusually high volume of waste generated by families and health-care institutions, which looks to be exacerbated by the hoarding of gloves, gowns, masks, and other protective apparel and equipment. Failure to appropriately manage waste created by health institutions and families may increase the spread of COVID-19 via secondary transmission (Atanu Kumar et al. 2021).

Medical waste can be infectious to both humans and the environment, posing a significant danger of contamination and cross-contamination. A medical waste treatment facility should be located close to the point of creation, according to references from the World Health Organization (WHO) and other standards. Every staff working in the hospital who is engaged in the segregation process must take personal accountability for their actions (Padmanabhan & Debabrata 2019). Hazardous materials may be transported less often if they are stored in an appropriate area and are properly prepared for disposal. When it comes to the transportation of biological waste, there is a considerable danger of unlawful or incorrect disposal by haulage workers, as well as the possibility of accidents. Furthermore, in certain metropolitan areas, the transportation of hazardous trash to treatment facilities is restricted (Diaz et al. 2005).

Alternative waste treatment technologies in the medical industry are being studied by Li et al. (2020), including their incineration, steam sterilization, microwave or ultraviolet heating systems as well as disposal in landfills; the results indicate that the established method is useful to help prioritize waste treatment technology in the medical industry. The selection of the most sustainable waste treatment technology in the medical sector in today's economies takes place according to the decision-makers who simultaneously consider various criteria.

Insufficient training in effective waste management, poor waste management, and disposal methods, and a lack of financial and human resources are all prevalent issues with healthcare waste. The health of people and the environment are at risk if biological waste is not properly handled. In recent years. The blood collection uses biodegradable blood sample paper. Biodegradation of biological waste outperforms all other traditional disposal methods in terms of efficiency and cost. It's also more eco-friendly (Jha et al 2014). Due to its ability to do rapid and low-cost diagnostics and analyses in non-laboratory settings, paper-based devices have shown to be perfect for performing blood tests. These advancements make paper-based devices more practical for doing point-of-care blood testing in many settings. Because medical waste harms both the environment and humans, it requires special care. This study evaluates the features of an alternative sample composed of gelatin-coated sample paper and covers sustainable treatment of blood sample bio-medical waste. A new bar-coded paper-based blood collection procedure has reduced problems and is more eco-friendly.

MATERIALS AND METHODS

A paper sheet is generated from a network structure formed by the interaction of cellulose and non-cellulose molecules. Hydrogen bonds are responsible for holding these materials together. By increasing the crossing between the cellulose fibers in a paper sheet, it is possible to increase the mechanical characteristics of these components in a paper sheet and create better mechanical properties overall. A variety of polymer compounds have been used to improve the interfiber bonding between the cellulose chains in the paper sheets that have been created. Increasing the breaking length and tear factor of paper sheets after they have been dipped in various polymer solutions has been shown (Battisti et al. 2017, Wang et al. 2020). When various polymeric materials are used to treat different types of paper sheets, the breaking length of the treated paper sheets may be increased. This can be attributed to an increase in inter-fiber bonding between the fiber and the polymer. Additionally, the polymeric substance includes functional groups that are capable of forming ionic or covalent interactions with the surface of the paper fiber. Most polymeric materials enhance the breaking length and tear factor of the treated paper sheets, which is generally a good thing (Kamel et al. 2004).

In part, because blood can serve as a window into one's health, it is the human biofluid that has received the greatest attention in scientific studies so far. An individual's general health may be determined by doing blood tests, which can be used to diagnose illnesses, assess the efficacy of treatment drugs, and collect information on a person's overall health. When subsequent treatment is required, it is becoming more important to do quick response blood tests (Linton et al. 2020). When it comes to performing blood tests in response to this need, paper-based devices have shown to be the most effective equipment because of their ability to do rapid and low-cost diagnostics and analyses in an environment other than the laboratory. Recent breakthroughs in paper-based blood testing are discussed, with a special focus on the specific procedures and assays that have been employed in each instance. Additional subjects explored in this work include how to enhance the signal intensity of these paper-based devices in the future, as well as how to use in situ synthesis of coating to improve the sensitivity, functionality, and operational simplicity of these devices (El-Sakhawy et al. 2018). Fig. 1 shows blood samples placed on a gelatin-coated paper.

For a broad variety of functional features, gelatin has been widely employed in the preparation of edible films and coatings. These characteristics include outstanding film-forming capabilities, a strong binding capacity with water, and emulsifying characteristics. Aside from that, it has a number of benefits such as cheap cost, high availability, biocompatibility, and biodegradability (Doppalapudi et al. 2014). As a result of their hydrophilic nature, gelatin-based films and coatings have a high water vapor transmission rate. When gelatin films come into touch with surfaces with high moisture content, their mechanical strength reduces as a result, limiting their use as packing materials. Nevertheless, it has also been reported that the crosslinking activity of the transglutaminase enzyme, which is believed to be a safe and efficient cross-linking agent, may be used to increase the mechanical characteristics and permeability of gelatin film (Nada et al. 2000, Banerjee et al. 2015).

GELATIN COATING

Gelatin seems to be inert and harmless when exposed to the human body. Biomedical device development will be aided by a thorough knowledge of nanoscale phenomena, which may be used to create antimicrobial surfaces, implants, and more. To better understand how gelatin is being used for biomedical purposes today, this study will concentrate on the most recent developments in that field's utilization and the most critical aspects that impact gelatin's biocompatibility, and the difficulties that lie ahead. Traditional disinfection techniques are not as successful as photocatalytic procedures thus, gelatin-coated surfaces with antibacterial qualities might be used in the healthcare business. Because gelatin-coated catheters are safe and have the potential for light disinfection for clinical usage, they are another interesting use of gelatin in biomedicine (Dupont 2002, Nur Hanani et al. 2014).

Figs. 3, 4, and 5 depict the effects of several gelatin-coating agents on the density, water absorption, air permeability, and bio blood sample paper sheets. Reduced air permeability, increased density, and higher water resistance are some of the functional features of this material. The permeability of the paper (also known as porosity) and the density of the paper are two more critical criteria to consider. Particle permeability of a paper web is a physical characteristic that describes the degree to which the web resists the passage of gas through it. The impact of varying concentrations of gelatin as a coating agent on the air permeability, water absorption, and density of coated bagasse paper sheets was investigated. The results clearly show that, when the proportion of gelatin-coating was increased, the air permeability of all samples reduced

Fig. 1: Blood samples on gelatin-coated paper with bar code.

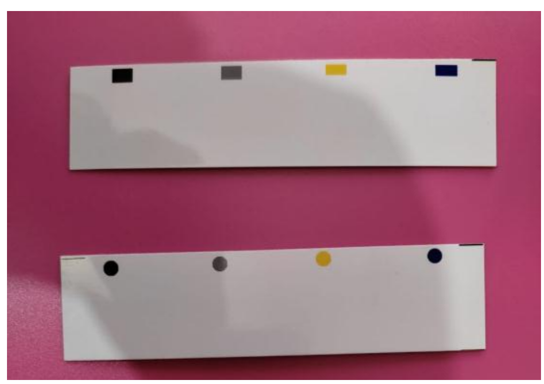

Fig. 2: Blood sample paper coated with gelatin with a color dot.

when compared to the control sheet. It has been shown that decreasing the number of spaces filled by gelatin enhances the resistance of the paper sheet to air movement. Only at 2 and 2.5 percent gelatin does water absorption demonstrate a significant increase in efficiency. The average apparent density of the blank sheet was 8 x10^5 g.m^{-3}, and the gelatin coating had a small effect on this parameter.

As seen in Fig. 5, when coated paper sheets were treated with a gelatin coating in contrast to the blank or with plain biopolymer, a significant decrease in air permeability was observed, as compared to the blank or with plain biopolymer. When applied to gelatin sheets, coatings have the potential to promote cross-linking while simultaneously reducing the free volume of the polymeric matrix. As a consequence, the diffusion rate of air molecules through the sheet is decreased, and the sheet's air permeability is lowered. According to Figure 4, coating with gelatin individually resulted in the largest increase in water absorption. Comparing the air

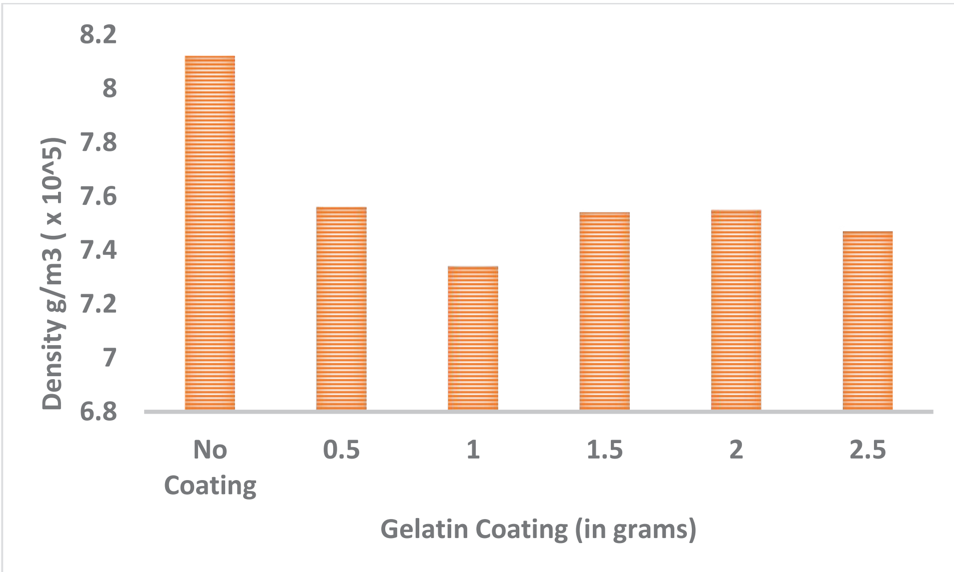

Fig. 3: Effect of gelatin coating on paper density.

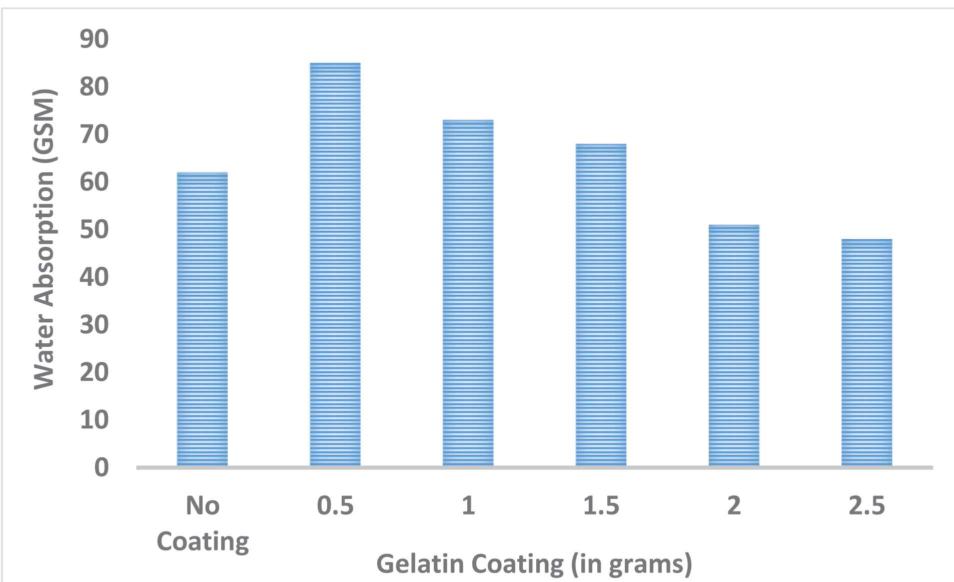

Fig. 4: Effect of gelatin coating on papers water absorption property.

permeability of the samples to the control sheet, the fraction of gelatin-coating was raised and the air permeability of all samples decreased. This is because the coating fills up the crevices between the paper sheets, hence increasing the resistance to the air passage. The application of gelatin to a substance increases the material's water absorption characteristics.

RESULTS AND DISCUSSION

At various spots along with an 8-inch piece of glass, three drops of red blood cells are collected to determine the person's blood type. Separately mixed with the samples obtained and examined will be the three antigens (A, B, and Anti-D). If the antigen interacts with the blood cells, it causes agglutination; otherwise, it stays the same as before. This is the method through which blood types are categorized. Laboratory assistants are more likely than not to handle hundreds of samples of such blood types at a time, and they are more likely than not to put the plates in an upside-down posture while doing so. When deciding on the tests for the samples that have been inserted in this manner (Jayakumar et al. 2020), it will be erroneously determined. It has been decided to implement a new color-coding scheme to avoid similar errors. In other words, color coding comparable to the colors of the antigens is affixed to the side of the coated paper, as indicated in the accompanying image. Laboratory assistants may then inject the example antigens in the proper locations during the test to accurately record the findings. According to the illustration in Fig. 4, a bar code is applied to the top of the blood sample paper, and we will go into further detail about this in a subsequent section.

A number of researchers used the sampling method using paper-based biological tests and were successful in their studies. To prevent the blood dot from escaping on the sides, the blood paper slide is constructed of gelation-coated paper with a thickness of 0.28 mm and is glued on a piece of cardboard that has been perforated with a circular brim. The four colored marks on the board (Fig. 6), which correspond to the standard presented on the board, are used to mix the blood with different antigens and see the outcome. The gelatin-coated coating on the slide prevents the blood liquid from blotting on the surface. If the slide is cremated after use, there will be no dangerous chemicals released into the atmosphere as a result of burning, preventing contamination of the environment (Hao et al. 2021). Each slide card is labeled with a barcode that allows the patient's information to be identified. The findings demonstrate that the suggested color-coding system helps to decrease the number of mistakes that occur. During the study period, blood type tests were carried out using the suggested color-coding method, and the results showed that there were no technical problems. Using this procedure, there is a minor expense associated with driving color components into a microplate that may be utilized in a blood categorization test; nevertheless, there is no major damage to the plate.

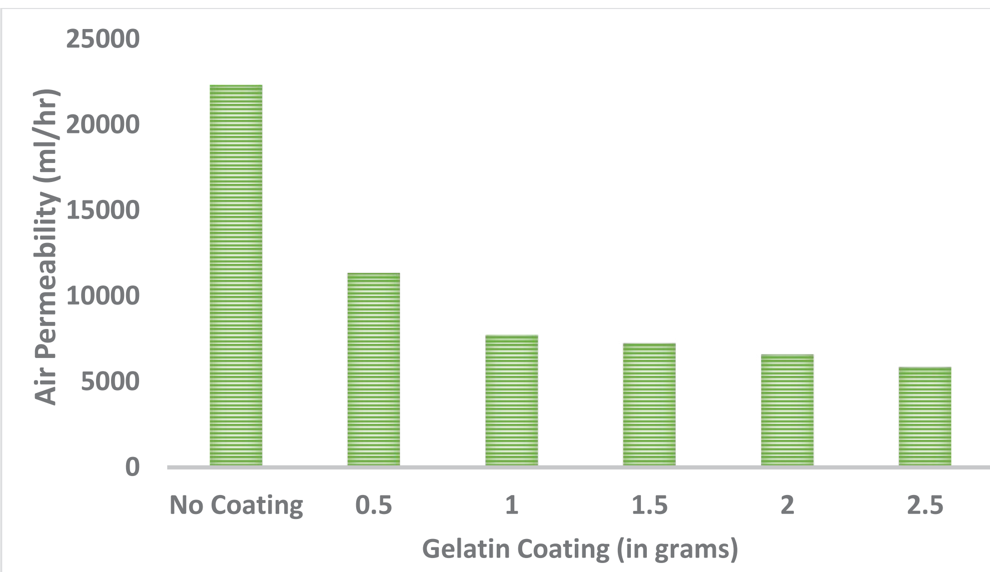

Fig. 5: Effect of gelatin coating on papers air permeability property.

Effectiveness of Blood Sampling

It is possible to use gelatin, as a retention agent, to keep supporting materials attached to a paper sheet after they have stuck to the sheet. In terms of the retention agent, there are two possible mechanisms: coating the sheet surface with a gelatin suspension and wet end addition, which involves depositing gelatin onto individual fibers before sheet formation, resulting in an even distribution of gelatin loading throughout the sheet (Jha et al. 2014). If, for example, gelatin and hexadecanoic acid are mixed, the surface properties of the resulting mixture demonstrate a considerable increase in wetting and dispersion. It was discovered that the gelatin-coated paper had a larger dynamic elastic modulus than the other sheets. As a consequence of this, researchers are attempting to develop a modern method of making advanced paper with a highly hydrophobic surface created by adding modified gelatin to cellulose fibers (Leila et al. 2017).

As a result, there was no obvious agglomeration problem between the coated particles, which shows that the gelatin particles may have been adequately coated on the blood sample paper during the blood sample papering process. In this particular instance, the irregular morphologies of the coated gelatin particles may be responsible for the uneven surface structure of the paper that was generated. Using blood sample paper (Figs. 7 & 8) for the creation of spots, researchers discovered a significant difference between the top and rear surfaces of both paper substrates (Tai et al. 2021). This was because the top and rear surfaces of both paper substrates

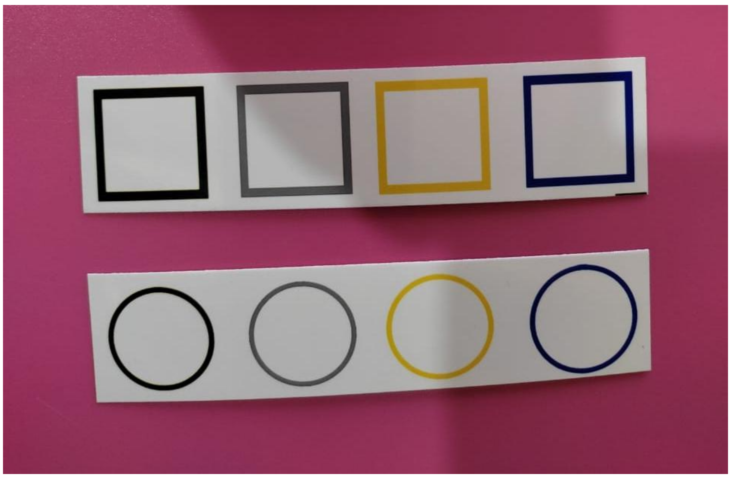

Fig. 6: Gelatin-coded blood sample paper with color code.

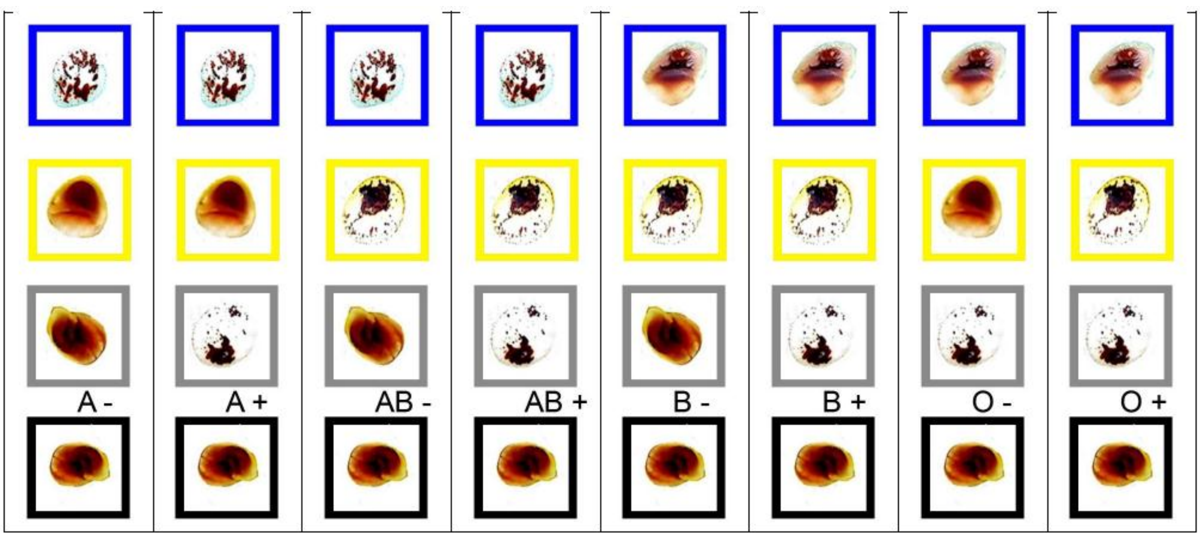

Fig. 7: Blood samples on gelatin-coated paper with bar code.

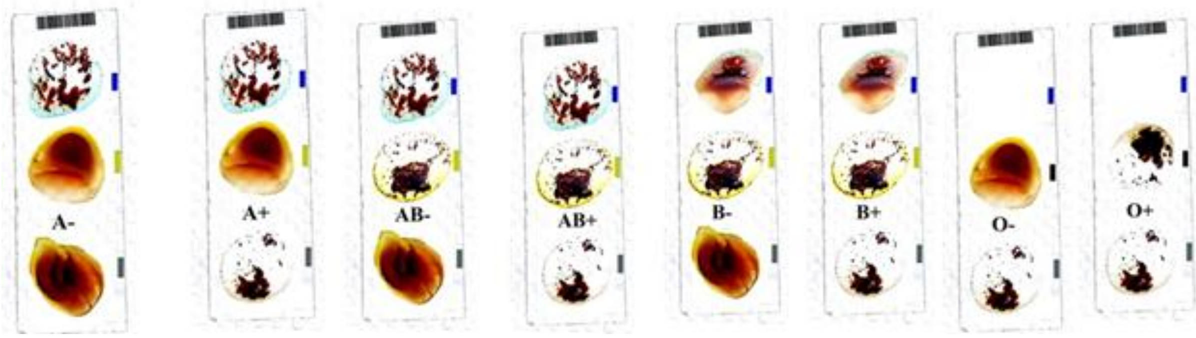

Fig. 8: Blood group identification on gelatin-coated paper.

were significantly different from one another. In the blood sample paper, it was proved that the applied bovine blood permeated the paper substrate in an even and uniform manner. The diameters of the spot on the top and back sides were both around the same size. As shown by the little difference between them, the color of the backside of the paper substrate inside the spot area was a shade or two darker than the color of the top surface. For example, when blood was deposited on gelatin-coated paper, the blood sample was completely blocked on the top side of the paper substrate and there was no prominent blood sample visible on the backside of the paper substrate, in contrast to the performance of commercially available polystyrene base paper (Gruner et al. 2015), which was demonstrated in Fig. 8.

That the one-sided gelatin-coated paper's surface could have caused this. In this way, the gelatin particles on top of the cellulose fibers contact directly with the blood sample, improving the experiment's efficiency. With the great ability of coated gelatin particles to adsorb blood and impede blood flow through the paper substrate, this may be helpful for spot detection of target compounds (Chauhan et al. 2013). A sub-punching approach may cause larger concentrations of blood samples between the edge and the center of the area. The uneven distribution of blood samples on the gelatin-coated paper results in a non-complete spot.

CONCLUSION

Water, air, and soil quality have all been compromised as a result of biomedical waste. The volumes and proportions of various elements of wastes, as well as their management, treatment, and disposal procedures, varied in different healthcare settings, and treatment and disposal methods are insufficient in the majority of research conducted on this subject matter. Various studies have discovered risks linked with inadequate biomedical waste management as well as inadequacies in the present system in blood sampling. It is discussed in this article that there are different concerns with the sustainable management of blood sample bio-medical waste, and it is evaluated the qualities of an alternative sample, which is made of gelatin-coated sample paper, in this study. A bar-coded paper-based blood sample technology has eliminated problems during blood testing and has made the process considerably more environmentally conscious. Biodegradable polymers, on the other hand, break down far more quickly than their conventional equivalents, which may take hundreds of years to degrade. When biodegradable materials decompose, carbon dioxide, water vapor, and organic matter are not detrimental to the environment. Because of this, they seem to be a better option in terms of sustainability. Humans have a moral imperative to safeguard the environment against pollution and other forms of environmental damage.

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