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Full Length Research Paper

Livestock waste and its impact on human health

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The Government of India currently has prime focus on construction of toilets to control open defecation, highly prevalent in rural India. India has about 512 Million livestock population and is largely affected by zoonotic diseases. Microbes are transported to the water bodies in slurry form. The total amount of dung produced is about 3 million tons annually. The main pathogen content of dung excreta is more than faecal extra. Pathogens are bacterial, helminthic, pathogenic and viral. Cattle excreta have more pathogens than human excreta, while human excreta have more fertilizer value than pig and cow manure. Per capita contribution of human excreta is about 450g in wet condition and 110g in dry condition. The die-off rate of pathogens depends on the temperature, moisture, UV light, type of organisms, and their environment. Modes of transmission of pathogens can be water-borne infection, water-washed infection, water-based infection and insect vector infection. These are prevented and controlled by improving water quality and quantity supplied of water by different state agencies, improving use of water, improving hygiene standards, reducing water body contamination by human and cattle excreta, controlling breeding of insects in water bodies, and use of mosquito nets and repellents at the household level.

Keywords: Safe water network, reverse osmosis, livestock pathogens, human sanitation campaign, individual household latrines, zoonotic diseases.

INTRODUCTION

Sanitation is receiving the urgent attention of Government of India (GoI), State Governments and different NGOs in India for the last few decades. The coverage of individual household latrines (IHHL) in rural areas increased from 1% in 1981 to 11% in 1991 and 21% in 2000. With the pace accelerating in the last few years, the coverage has increased but still about 65% human population defecate in the open. In a boost to making rural India free from open defecation, the GoI has increased the grant for construction of a toilet under Total Sanitation Campaign from INR 4,600 to INR 10,000. This increase in financial aid is done because the toilets made with lesser funds have turned into storerooms. To achieve the objectives and goal of total sanitation campaign, the planning commission is likely to increase the allocation for sanitation campaign from INR 7,800 crore ($ 1.5 billion) in the 11th Five Year Plan to INR 36,000 crore (approximately $ 6 billion) in 12th Five Year Plan[81].

Livestock rearing is an integral part of the Indian culture and is an important component of the agriculture and economic activities. The domestic and commercial livestock includes cattle, buffalo (heifer), sheep, goat, camel, pig, chicken, etc. Cows and buffaloes are the main milk producing animals and constitute 59% of the total livestock population in India. India is the highest milk producer in the world. The average milk produced by dairy cattle is 2.1 kg/day. The buffaloes produce 3.5 kg/day. The livestock population was 530 million in 2007. The dairy cattle and buffalo population were about 200 million and 105 million respectively in 2007, and 190 million and 109 million population respectively in the year 2012. The cow excretes 10 $\pm$ 2 kg cattle dung and 5 $\pm$ 1 L urine per day; [80]Therefore, considering 190million cattle populationas per Livestock Census 2012 and ~10kg of cattle dung production, the total annual production of cattle dung is 730 million tons. The total amount of dung produced in 1997 and 2003 was 270 and 268 million tons annually respectively. About 50% of cattle dung is used for the preparation of dung cakes used as fuel in rural India[50]. The remaining 50% is a serious health hazard for the communities living in the vicinity and consuming contaminated water due to this large quantum of excreta.

India has topped a list of countries worst-affected by zoonotic diseases with widespread illness and death followed by Ethiopia, Nigeria and Tanzania. The first-of-its-kind global study mapping human-animal diseases has pinpointed an "unlucky" 13 zoonoses that are responsible for 2.4 billion cases of human illness and 2.2 million deaths per year. Globally, 60% of all human diseases and 75% of all emerging infectious diseases have been found to be zoonotic. The International Livestock Research Institute (ILRI), Kenya and the Institute of Zoology, UK reported that most of these human infections were acquired from the world's 24-billion livestock. The study showed that 27% of livestock in developing countries like India showed signs of current or past infection with bacterial food-borne disease — a source of food contamination and widespread illness.

The 13 zoonoses were identified as most important. At least one-third of global diarrheal diseases are because of zoonotic causes. From cyst-causing tapeworms to avian flu, zoonoses present a major threat to human and animal health. 80% of pathogens — with a high potential for bio-terrorism — are zoonotic[74].

While a lot of focus is being given on human excreta for the prevention and control of mortality and morbidity of humans, but very little attention or effort is paid for controlling the animal excreta, which also pollutes the water bodies equally, if not more. It was therefore thought worthwhile to conduct a literature survey to understanding the diseases of zoonotic origin.

Movement of Faecal Microbes from Livestock into Water Bodies

Livestock manure is able to enter river and other water bodies by a variety of methods. First, some animals (cattle, sheep) graze on pasture lands, and deposit manure directly onto the surface of agricultural fields. In addition, animals are housed indoor and manure spread onto or injected into fields. Manure is stored prior to application on fields, or often applied without storage.

The potential for movement of faecal microbes into water depends on: how manure is applied to fields, whether manure has been stored prior to application, proximity to river or depth of ground water, and rainfall quantity and timing. Grazing generally allows for greater movement of faecal microbes into water than does application of manure[86]. With precipitation, manure is converted into slurry and slurry appears to move into soil more easily and then attach to soil particles. It has been shown that E. coli count decreased with the length of time a rain event occurred after application[86]. Storage of manure reduced E. coli concentrations due to microbial die off, with 99+% reductions in E. coli concentrations in runoff, if manure was stored for 30-90 days[53]. Fresh manure applied to fields (i.e. no storage) produced greater E. coli concentrations in run off than did aged manure[82]. In fact, measurement of E. coli concentrations in soil after application of fresh manure showed increased concentrations with time, implying that E. coli was able to replicate in soil. This was not the case with aged manure[82].

The most important factor in determining the amount of movement of faecal microbes into surface water is rainfall. First, the more water in the soil, the greater the movement of E. coli from fields to river[52]. These organisms generally move into drainage tiles and then into surface water. Second, rainfall events, in amounts exceeding 20 mm, can wash manure applied to the surface of fields into adjacent ambient water[52,82]. It was reported that during dry periods in summer, the water table is lowered and ground water cannot be easily contaminated by surface water[26]. The time gap between manure application and the rainfall event decreased runoff and microbial concentrations in streams[53]. Tilling manure into soil slowed the movement of indicator bacteria into waterways following rainfall[53].

Agricultural Best Management Practices have been established to help reduce or eliminate the movement of faecal microbes into surface water[53,72,83].

Preventing faecal contamination of water in three productive ways:

- Storage of manure prior to application
- Elimination of manure application associated with precipitation
- Maintaining distance between farm and water surface with buffer stripes

It is projected that the world population will reach 7.7 billion by 2020 and 9.4 billion by 2050, the largest increase coming from the developing world. Over the last 25 years, the per capita meat and dairy consumption in developing countries has grown 3 times the rate in developed countries. If current trends continue, diets will continue to shift from plant based to increased consumption of meat and dairy products. It is estimated that global livestock production will need to double by 2020 to supply needs. Consequently, it would increase the production of manure and its pollution potential, if corrective remedial measures are not taken on urgent basis.

There are approximately 1.2 billion cattle, 800 million pigs and 10 billion chickens in the world. Of the cattle and pigs, three-quarters are resident in the developing world. Intensive systems of animal agricultural are increasing at the rate of 4.3% per year with much of that increase in Asia, South America and North Africa[7].

Applications to fields is the time-honoured manner of manure disposal but it can cause considerable problems with nitrate leaching if there is excess rain or soil is very sandy. The runoff of manure into watersheds cause increased microbiological proliferation, high BOD and altered aquatic microenvironments[36]. It is estimated that in 2020, there will be 18 billion tons of animal wastes for disposal[22].

The tonnage of animal waste has been estimated based on nitrogen in animal excreta[6], but no effort has been made to address the microbial and zoonotic infectious disease potential due to these changes associated with loading of manure onto land and water. Faeces and urine from both humans and other animals are likely the largest source of environmental loading of pathogens associated with waterborne disease transmission.

A wide variety of pathogenic bacteria, viruses and parasites may be found in the excreta of livestock and human being. Non-pathogenic bacteria and parasites are found in large numbers in the excreta of animals as well as soil and water. Of the existing microbes in the universe, only a small number of microbes impact human and livestock health adversely. These harmful microbes are called pathogens. Table 1 shows the prevalence of enteric pathogens in human and cattleexcreta.These are the pathogens that impact health of the communities adversely who are exposed to these through consumption of food and water with faecal and animal contamination. Survival of animal faecal pathogens in the environment is given in Table 2 and effect of temperature on their survival is given in Table 3.

Water polluted by inadequately treated sewage and animal dung carry pathogens like bacteria, parasites and virus that pose serious threat to human health. They range in severity from mild disposition to life threatening illness. Diarrheal diseases due to contamination of food and water claimed more than three million lives in 1995 of which more than 80% were among children under age 5[89]. It is difficult to decide which pathogens are serious threats to human health. Nevertheless, there are some specific pathogens that are described briefly in Table 4.

Livestock Faecal Pathogens

The main livestock are dairy and beef cattle, swine, sheep and poultry. Faeces from each livestock species contains a varied population of normal gut flora and pathogens, and represents risk to human health.

Cattle: Cattle, both dairy and beef, are present in high numbers around the world. The cattle pathogens likely to cause risk to human health are: E. coli, Campylobacter, Salmonella, Cryptosporidium parvum, and norovirus.

Swine: Canada and the US are both important swine producers in the world[17]. The enteric pathogens most likely present in swine manure include Clostridium perfringens, pathogenic E. coli, Salmonella, Campylobacter, Cryptosporidium, Giardia and norovirus. Of these, E. coli O157:H7 is most likely to survive manure storage and contaminate water. Campylobacter and Giardia have the greatest die offs in manure and would be less likely to contaminate water[29].

Poultry: Chicken and turkey manure contains a variety of microbes potentially pathogenic to humans. Most important as pathogens are: Salmonella, Campylobacter, and Clostridium perfringens. Cryptosporidium is not detected in poultry manure[18]. Poultry litter (manure) contains faecal coliforms in concentrations (up to 9.5 x 10^8 CFU/g wet weight) greater than in the other livestock species[75]. Manure is stored and often dried prior to application to agricultural fields. The process of storage and drying can reduce microbial concentrations in manure. Application of dried turkey litter to fields resulted in lower E. coli concentrations in field runoff than if cow manure was applied.

Sheep: Sheep production has an important place in animal agriculture. The zoonotic pathogen most likely to be present in sheep manure is Campylobacter, Salmonella, E. coli O157:H7. Cryptosporidium parvum and Giardia are not frequently isolated from sheep manure[69,78].

Pathogens associated with Livestock Manure

Manure from different animal species contains many of the same potential pathogens for human, although concentrations of pathogens in faeces can vary with host species[3]. Microorganisms in livestock manure with potential to cause diseases in humans include bacteria, viruses, helminth and protozoa.

Bacterial Pathogens

A large number of bacterial pathogens found in manure from livestock have the potential to cause illness in humans. These organisms include, but are not limited to, *Salmonella*, *Campylobacter*, *E. coli*, *Leptospira*, and *Clostridium* spp.[84]. Most of these organisms have been shown to cause gastrointestinal disease when faecal material from livestock has contaminated food or drinking water[11], and in fewer instances when faeces have contaminated water[13,20].

E. Coli

Enteropathogenic Escherichia Coli are present in the faeces of human and animals. They cause pollution of lakes and rivers. E. coli 0157: H7 produce potent toxins that can cause severe illness in humans. About 15% of cattle shed E. coli 0157: H7 and up to 99% produce toxin. The risk to humans occurs when it contaminates food and drinking water supplies[12,14]. The bacteria can be transmitted from one infected human to another through

Table 1. Prevalence of Enteric Pathogens in Humans and Cattle.[60]

Pathogens	Human	Cattle
Salmonella spp	1%	0-13%
E. Coli O157:H7	1%	16%
Campylobacter jejuni	1%	1%
Yersinia enterocolitica	0.002%	<1%
Giardia lamblia	1-5%	10-100%
Cryptosporidium spp	1%	1-100%

Table 2. Pathogen and Indicator Survival in Different Environmental Media.[25,49]

Organism	Freshwater	Saltwater	Soil	Crops
Ascaris Eggs	1.5 years	2 years*	1-2 years	< 60
Cholera	30	+ 285	< 20	< 5
Faecal Coliforms	< 10	< 6	< 100	< 50
Protozoan Cyots	176	1 year	+ 75	ND
Salmonellae	< 10	< 10	15-100	5-50
Tapeworm Eggs	63*	168*	7 months	< 60
Termatodes	30-180	< 2	< 1*	130**
Virus	11-304	11-871	6-180	0.4-25

Note: ND = No Data
* = Not considered an important transmission pathway
** = Aquatic macrophytes.

Table 3. Survival of Animal Faecal Pathogens in the Environment[60]

Material	Temperature	Duration of Survival					
		Giardia	Cryptosporidium	Salmonella	Campylobacter	Yersinia entercoliticia	E. coli O157:H7
Water	Frozen	< 1 day	> 1 year	> 6 months	2-8 weeks	> 1 year	> 300 days
	Cold (5C)	11 weeks	> 1 year	> 6 months	12 days	> 1 year	> 300 days
	Warm (30C)	2 weeks	10 weeks	> 6 months	4 days	10 days	84 days
Soil	Frozen	< 1 day	< 1 year	> 12 weeks	2-8 weeks	> 1 year	> 300 days
	Cold (5C)	7 weeks	8 weeks	12-28 weeks	2 weeks	> 1 year	100 days
	Warm (30C)	2 weeks	4 weeks	4 weeks	1 week	10 days	2 days
Cattle Faeces	Frozen	< 1 day	> 1 year	> 6 months	2-8 weeks	> 1 year	>100 days
	Cold (5C)	1 week	8 weeks	12-28 weeks	1-3 weeks	30-100 days	>100 days
	Warm (30C)	1 week	4 weeks	4 weeks	1 week	10-30 days	10 days
Slurry		1 year	> 1 year	13-75 days	> 112 days	12-28 days	10-100 days
Compost		2 weeks	4 weeks	7-14 days	7 days	7 days	7 days
Dry Surfaces		1 day	1 day	1-7 days	1 days	1 day	1 day

poor hygiene. Ingestion of just a few organisms can lead to disease. Its infection may cause severe bloody diarrhoea and abdominal cramps. In young children and the elderly, the infection can cause a serious complication called Uremic syndrome where the red blood cells are destroyed and kidneys fail to function.

Yersinia enterocolitica

It is a bacterium present in the faeces of pigs and cattle that causes fever, abdominal pain and diarrhea[70]. Exposure to pig faeces is considered an occupational risk for yersiniosis. Swine slaughterhouse workers and farmers

Table 4. Pathogens responsible for different diseases in India.

Pathogens	Diseases
Virus	
Polio	Poliomyelitis
Hepatitis A	Infective Hepatitis
Rota Virus	Diarrhoea
Protozoa	
Entamoebahistolytica	Amoebiasis
Giardia lambia	Giardiasis
Bacteria	
Salmonella typhi	Typhoid
Vinrocholera	Cholera
Campylobacter jejuni	Diarrhoea/Dysentery
Yersinia enterocolitica	Diarrhoea/Dysentery
Shigella	Dysentery
Helminth	
Enterobiasvermicularis	Thread worm
AscarisLumbricoidco	Round worm

are considered to be at risk of developing diarrhoea associated with *Yersinia enterocolitica*. In India, the outbreak due to these organisms was reported in 1997 from the north Arcot district, Tamil Nadu[1]. The origin of this was traced to contaminated well water and many persons were reported taken ill due to gastroenteritis. A several fold increase in the antibody of *Y. enterocolitica* was detected in the sera collected and this organism was also identified from the stool of these patients. *Y. enterocolitica* was also isolated from wastewater, pork, pigs and stool of diarrhea human subjects.

Salmonella

Salmonella is usually transmitted to humans by eating foods contaminated with animal faeces[28,80]. Water may be contaminated by animals defecating in water or through runoff following heavy rainfall in the catchment area. Human infections occur when untreated water is consumed or used to wash uncooked foods. Contaminated manure used to fertilize unprocessed food viz. lettuce, sproutsand mushrooms may be a source of human infection. Food may also be contaminated by food handlers who do not thoroughly wash their hands before touching food. Salmonellosis is caused by many species of salmonella and the disease is observed in all animals and occurs worldwide. Faeces of infected animals can contaminate animal feed, water, milk, fresh and processed meats, and plant and animal products. People infected with these organisms develop diarrhoea, fever and abdominal cramps 12 to 72 hours after infection[80]. The diarrhoeain some people is so severe that it may require hospitalization and infection can occasionally spread to the blood stream and other body sites. Sometimes, it is proved fatal.

It may survive in manure for up to three weeks and in slurry manure for up to five weeks. It can be detected in manure seepage water for 42 days indicating thereby that care must be taken to control runoff from manure and compost piles. It can survive in water for months and cold water acts to prolong viability. It is not inactivated by freezing and is relatively resistant to killing by drying and freezing.

Campylobacter

*Campylobacters jejuni*are becoming increasingly important as cause of acute gastroenteritis transmitted by water, unpasteurized milk and poultry products. *Campylobacters* have been reported to be high in numbers in raw sewage and they occur in faecal-contaminated surface waters. Recently *C jejuni*were isolated from a groundwater source, probably contaminated by cows of a dairy farm. They have been associated with several outbreaks from drinking water. Conventional chlorination of water destroys the bacteria[39]. Composting manure leads to the elimination of campylobacter within a week although the organism can survive for several weeks in manure. There is a substantial risk of contracting and developing campylobacteriosisfrom drinking unprocessed surface water.

Livestock contaminate water by defecation in unprotected surface water, through run off and as a result of seepage of water through soil that contains an excessive amount of livestock dung.

Livestock dung has pathogens infectious to both human and livestock alike. As a result, livestock are incriminated with water borne and food borne out breaks. It is critical for human and livestock health and agriculture sustainability that water and food supplies be protected from contamination of human as well as livestock excreta.

There are large number of livestock parasites that can cause infections in human and are widely prevalent in tropical and developing countries. These parasites are AscarisSumm, Giardia and Cryptosporidium.

Helminthic Pathogens

Helminthic parasites are divided into three major groups: nematodes (roundworms), cestodes (tapeworms), and trematodes (flukes). Ascaris is a nematode causing parasitism in the human intestine. Man is the reservoir for this worm. There are similar species in pigs, dogs, cats and horses. The pig species Ascarissuum may also infect people in endemic areas. Coprophagous animals like pigs, dogs, cats and chickens disperse and spread the eggs over a wide area. Ascaris eggs are widespread in the environment in surface and ground water, marine, brackish and fresh waters, sewage, sludge, soils, crops and beaches. In temperate climates, eggs can remain viable in moist loose soil for several years, longer buried in wet clay.

Chlorine and chloramine are ineffective against Ascaris eggs but coagulation and filtration does remove them from water and UV will destroy them. They remain viable in septic systems for about a year; conventional sewage treatment is not effective, the sludge contains large numbers of infective ova. Faecal-contaminated soil, food and water are vectors.

Ascarissumm and Ascarislumbricodes

Ascarislumbricodes is the largest intestinal round worm in human beings and is especially common in the tropics and sub-tropics. *Ascarissumm* is a common round worm of pigs. Pigs and humans become infected by ingestion of eggs that developed to an infective stage in the environment. After hatching, the larvae penetrates the gut wall in migrate to the lung passing through the liver. *Ascaris*produces ill thrift, stunting, pot-belly and diarrhoea. Humans are infected by exposure to infective eggs.

Ascaris eggs were identified in 1% of legume samples. *Ascarissumm* eggs under dry conditions survive for 2-4 weeks while under moist and cold environment, they can survive for over 8 weeks. The eggs were highly resistant to inactivation in the environment and within faeces[59]. They can remain viable in soil and faeces for years.

Composting of manure reduces the number of eggs although this does not eliminate them completely. To break the cycle, pigs should not be exposed to soil or faeces where infected animals were previously housed or their contaminated manure was spread on fields.Humans should avoid contact with contaminated soil and water. *Ascaris*was identified in 60% of 50 Alberta farms but only 8.5% of livestock were infected.

Protozoan Pathogens

It has been reported that Cryptosporidiumoocysts can be found in 39-87% of US surface water[44]. The watersheds with the greatest proportion of agricultural land use had the greatest concentrations of Cryptosporidium parvumoocysts (90% with bovine genotype)[45]. Cryptosporidium and Giardia are found in the faeces of humans and other mammals (including livestock such as cattle, sheep and swine), can be transmitted between species, and can cause disease in a wide variety of hosts[3,18]. Human disease was attributed to these protozoa in more than 20% of outbreaks associated with recreational water, and the bathers themselves were important sources of the contamination[19].

Cryptosporidium

This organism is transmitted primarily by ingestion of water contaminated with the oocysts of cryptosporidium. It has caused large water borne disease outbreaks in several parts of the world[75]. One of the largest water borne outbreak was reported in 1993 in Milwaukie, Wisconsin involving an estimated 0.4 million cases. The oocyst of cryptosporidium is resistant to chlorination. The water borne pathogens has much more relevance to India because of ever increasing number of patients having such symptoms. In India, the detection rate varies from 4.3 to 13%[21,60]. Most human infections are acquired by person to person transmission and through consumption of drinking water contaminated by effluent[60]. Cryptosporidium partum infects human and a variety of domestic livestock (cattle, pigs, horses, sheep, dogs and wild animals alike). Young and immunosuppressed have severe watery diarrhoea.

Giardia

The domestic livestock (cattle, sheep, pigs and horses) are host for Giardia[59,61,62]. These parasites colonize the small intestine of the animals and humans leading moderate to severe diarrhoea. It produces highly resistant cyst that are shed into the environment. The cyst have a protective carbohydrate wall that makes them resistant to environmental destruction and are only destroyed by desiccation, heat, UV radiation and high concentration of biocides. The cysts are highly infectious and can cause infection and disease. The prevalence of giardiasis in humans is 2-7% in Europe and North America whereas it can be as high as 40% in developing countries. It is transmitted through faecal-oral infections. Water contamination is associated with sewage and agriculture run off. It can survive for months in water and are resistant to chlorination. It can be removed by ultra-filtration or inactivated by boiling water. The WHO has recommended that Giardia infection be considered as zoonosis.

Infection in domestic ruminants are of special concern because the potential contamination of surface and ground waters through pasture runoff and use of manure as a spray on field outbreaks from waterborne giardiasis in humans have been attributed to pasture runoff leading to drinking water contamination. Sewage irrigated vegetables are one of the major causes of giardiasis. Foodborne infections have been associated with poor hygiene in food handlers and washing food with contaminated water[92].

The cysts have a protective carbohydrate wall that makes them resistant to environmental destruction and are only destroyed by desiccation, heat, UV radiation and high concentrations of biocides (bleach)[92].

Viral Pathogens

There are over 100 different pathogenic viruses found in human and animal waste[54]. There are a few viruses that have been shown to have zoonotic transmission or at least the potential to cross from animals to humans, and thus have the potential to cause disease in humans[51]. These livestock viruses with potential to cause recreational waterborne infections include hepatitis E, some members of the rotavirus group, and the noroviruses[46].

Hepatitis E virus: It is an RNA virus transmitted via the faecal-oral route. Infections in humans are usually from waterborne sources, with most infections associated with ingestion of contaminated (by human faeces) drinking water or improperly cooked contaminated shellfish[90]. Pigs, cows, sheep, and goats are susceptible to infection by similar, but species specific virus forms, with swine hepatitis E virus endemic in swine herds in the US and Canada[56,65,90]. Most infections of humans occur, however, in endemic areas of developing countries in Central and Southeast Asia, North and West Africa, and in Mexico[43].

Rotaviruses: These are pathogens of livestock (pigs, cattle, etc.), causing diarrheal disease especially in young animals[56]. Rotavirus of domestic animal origin has been shown to cross species and infect humans[15]. As with hepatitis E virus, there is close identity between human and animal rotaviruses, and cross-species transmission is possible, but only at a low frequency[15].

Norovirus: Bovine and swine norovirus can enter waterways from agricultural runoff. Prevalence of norovirus in faecal samples from swine and cattle ranged from 2-25% and 2-72%, respectively[51]. Age of animal, breed, and season can affect norovirus prevalence in feces. Swine norovirus is closely related to human norovirus. Norovirus has been detected in surface and groundwater in many parts of the world. The infectious dose for the virus is very low ($10\text{-}<10^4$)[47]. There have been many outbreaks of gastrointestinal disease attributed to infection from waterborne norovirus[5,9,32,35,64].

Avian Influenza (H5N1): This virus is mostly transmitted through recreational water. Wild waterfowl are one of the main reservoirs for the virus[91]. Birds shed the virus in large amounts through faeces, as well as through saliva and nasal secretions. Avian influenza virus has been recovered from surface waters around the world (including the US and Canada), especially where ducks flock and deposit faeces[30,34,38]. Human contact with virus in water is possible, as the virus is able to survive in water for extended periods, although different authors have shown vastly different survival times for the virus depending on pH and temperature[91].

Domestic birds (chicken, ducks and turkeys) have been shown to become infected with avian influenza virus, especially where they have had direct contact with wild waterfowl. If virus-contaminated waste of poultry enters water, it poses risk to humans. While most cases of influenza in humans are transmitted via aerosols and inhalation, it appears that humans may also acquire avian influenza through the faecal-oral route[91]. Close contact with infected birds has been the primary means of transmitting avian influenza virus to humans, but there are at least two cases in Southeast Asia, where it appears that recreational contact with water heavily contaminated by the virus was associated with infection[16]. In at least one case, the recreational water was used to dispose of dead poultry.

Human Excreta

The human excreta per capita quantities and their resource value are given in Table5. Faeces, urine and excreta production is 250 g, 1200 g and 1450 g respectively in wet condition, whereas in dry condition, their values are 50 g, 60 g and 110 g respectively. The chemical compositions of faeces are in respect of carbon – 4-8%, nitrogen – 4-7%, phosphorus pentoxide - 4% and potassium oxide – 1.6%. The urine composition has carbon – 13%, nitrogen – 14-18%, phosphorus pentoxide – 3.7% and potassium oxide – 2.7%. The urine has more nitrogen and potassium than faeces, whereas faeces have more phosphorus than urine.

The nitrogen, phosphorous and potassium values of human excreta, plant matter, pig manure, cow manure, and fresh night soil are compared with each other. It can be observed that human excreta have more fertilizer values than pig manure and cow manure in respect of nitrogen, phosphorous and potassium.

The volume of urine and faeces produced varies from regions to regions. It depends on the age of a person, water consumption, climate, diet and occupation. Diet influences the volume of faeces according to the differences in the digestibility of the food. Food low in fibre produces smaller quantity of faeces than food high in fibre that has in addition on higher moisture content[85]. The amount of urine produced depends upon very much on temperature and humidity and ranges commonly 0.6 to 1.1 litres per person per day[87]. The urine and faeces content vis-à-vis food diet and nutrient content are shown in Table6.

In order to know the amount of faeces and urine excreted in a situation, direct measurement is necessary. The WHO suggests that in the absence of local data, the following figures can be used as reasonable averages[88]. Table7 gives faeces and urine content of high protein and vegetarian diet in kg per capita per day.

The following relation is found between the food supplied according to the FAO and the excretion of Nitrogen and Phosphorous in total:

N = 0.13 grams of protein in total foodP = 0.011 grams of

Table 5. Human Excreta per capita quantities and their resource value[64]

	Faeces	Urine	Excreta
Quantity and Consistency			
Gram/capita/day (wet)	250	1200	1450
Gram/capita/day (dry)	50	60	110
Including 0.35 litres for anal cleansing gram/capita/day m^3/cap/year upon storage and digestion for ≥ 1 year in pits or vaults in hot climate water content			0.04 - 0.07 50 - 95
Chemical Composition			
Organic matter	92	75	83
Carbon, C	48	13	29
Nitrogen, N	4-7	14-18	9-12
P_2O_5	4	3.7	3.8
K_2O	1.6	3.7	2.7
Comparison with other wastes (% of dry solids)	**N**	**P_2O_5**	**K_2O**
Human excreta	9-12	3.8	2.7
Plant matter	1-11	0.5-2.8	1.1-11
Pig manure	4-6	3-4	2.5-3
Cow manure	2.5	1.8	1.4
Fresh night soil	10.4-13.1	2.7-5.1	2.1-3.5

Land Requirement = 0.02 – 0.07 m2/capita comprises faeces, urine and ablution water.

Table 6. Effect of Diet on Excreta[40]

Characteristics	Urine liter/capita/year	Faeces kg/capita/year
VOLUME (WHO 1992)		
High protein diet, temperate climate	440	44
Vegetarian diet, tropical climate	370	146
Pathogen Content	**Nil**	**High**
NUTRIENT CONTENT (SEPA 1995 and Wolfgast 1993)		
% N of total excreted amount	70-88%	12-30%
% P of total excreted amount	25-67%	33-75%
% K of total excreted amount	71%	29%
Relative Organic Content	**Low**	**High**

protein in total food + grams of protein in vegetable food

The Infectious Dose

The infectious dose is the number of pathogens which have to enter the body of a susceptible person to cause infection. The infectious doses of several faecal-oral infections are given in Table8. These figures are not exact, but give an indication of how easily an infection can occur. As each larva of a helminth can become an adult worm, worms have a very low infectious dose. Several bacteria can multiply in food, and thus reach the infectious dose in this way. Flies are more likely to transmit infections with a low infectious dose.

Die-off

Die-off or survival of excreted pathogens is an important factor when considering the public health dimension of diseases. In principle, all pathogens die off exponentially upon excretion, however, at different rates. The pathogens and their survival in different environmental media are given in Table2 & 3. The main factors influencing the die-off are temperature, moisture and UV light. Die-off rates increases/decreases in proportion to the level of intensity of these variables. Ammonia is known to be bacteroides. Therefore, die-off is enhanced at pH ≥8.5-9 due to increase in the NH_3/NH_4ratio. The infective dose of pathogens required for a human host to

Table 7. Faeces and Urine Content in High-protein and Vegetarian diet.

Diet Types	Faeces (wet mass) kg/cap/day	Urine l/cap/day
High-protein diet in a temperate climate	0.12	1.2
Vegetarian diet in a tropical climate	0.40	1.0

contact the disease. The infective doses of faecal-oral diseases and their die-off rates are given in Table8.

Microbiological Testing of Water

Faecal coliform and faecal streptococci are estimated as per Standard Methods for the Examination of Water and Waste water. The ratio of faecal coliform bacteria to faecal streptococci (FC/FS) present in the water sample is considered useful in providing a clue to the source of origin of faecal pollution in water.
If the coliform number is 4 times more than streptococci, it indicates faecal contamination of human origin and if it is less than 0.7, it would suggest the pollution consists of animal origin. The source of pollution and their relationship with faecal coliform / faecal streptococci is shown in Table9.
These ratios are valid only for recent (within 24 hour) pollution.

Mode of Transmission

The faecal oral pathogens and their transmission routes are given in Table10 and classification of water related diseases and their mode of transmissions are given in Table11.
The waterborne infections are mostly transmitted through the following routes:

1. **Waterborne infection**: Most of the pathogens are excreted with the cattle dung and stool of the infected livestock and people. The excreta containing pathogens may contaminate the water body and healthy person drinking water may suffer from the disease. This transmission infection is commonly known as faecal-oral infection. The pathogens can be of different types, viz. bacteria, helminths, protozoa and virus, which can cause various diseases.

2. **Water washed infection**: The water-washed diseases are caused by infection of skin and eyes as a result of poor hygiene in terms of hand washing practices and cleaning of utensils. Pathogens enter the body through breaks in the skin or mucus membranes, such as eyes. The eye infection, trachoma, is very common in tropical countries. It may lead to blindness if not treated adequately. Bacterial skin sepsis, scabies and fungal infection of the skin are widely prevalent in India and other tropical countries. These infections are related to poor personal and domestic hygiene and it is anticipated to reduce / control by increasing the volume of clean water supply and personal hygiene such as bathing and frequent hand washing. The improvements in hygiene practices mostly depend on the availability of clean water in good quantity. The diseases are described as water washed diseases and relevance of clean water to these diseases is of paramount importance.

3. **Water based infection**: Water based diseases are those in which the pathogens spend a part of its lifecycle in water, e.g. snail and cyclops. The diseases are due to infection by parasitic worms which depend on aquatic intermediate host to complete their lifecycle. Guinea worms are the most common examples which were prevalent in the 20th century, mostly in Rajasthan. It was caused by drinking well water from step wells as the infected persons dip their infected feet into the water passing on the infection in the water. These are known as water based diseases. These are generally controlled by water filtration and adequate chlorination of water which kills cyclops. This disease has been eradicated from India.
Water based infections are warm infections in which the infection must spend a part of their life in aquatic environment. This is acquired by two methods, one, by ingestion of water and second, disease acquired by coming in contact with water contamination with species of trematodes, genus Schistosoma e.g. guinea worm and schistosomiasis. The eggs of Schistosoma worms enter the aquatic environment from the urine or faeces of infected human. Dogs, cats, pigs, cattle, horses and wild rodents may serve as a reservoir of Schistosomajaponieum. The eggs hatch in water to produce miracidia, which infects snails, develop into the infective stage and are shed by snails into water over a period of a month. Humans are infected when the free swimming infective larvae penetrates the skin during water contact[8].
Lectospira species are neither aquatic organism nor enteric organism but enter water via the urine of infected domestic and wild animals[24]. Leptospirosis is one of the most widespread zoonotic diseases worldwide and occurs in urban and rural areas of both developed and developing countries.

4. **Insect vector infection**: Insect vector infectious diseases are caused by insects and micro-organisms that either breed in water or bite near water, e.g. Malaria, Dengue,

Table 8. Infective Doses of Faecal-oral Diseases and their Die-off Rate.

Disease	Infectious Dose (approx. number of pathogens)	Die off Rate
Shigellosis	10 - 100	
Giardiasis	10 - 100	0.171
Rotaviral Enteritis	100 – 10,000	
Cholera	10^6 - 10^8	0.331
Typhoid	10^3 – 10^9	
Total Coliform		0.310
Enterococci		0.078

Table 9. Source of Pollution vis-à-vis Ratio of Faecal Coliform Bacteria to Faecal Streptococci.

> 4	Evidence suggests that the pollution is of human origin
2 – 4	Good evidence of predominance of human waste along with domestic animal waste
1 – 2	Good evidence of predominance of domestic animal waste of along with human waste
< 0.7	Strong evidence of domestic animal waste origin

These ratios are valid only for recent (within 24 hour) pollution.

Table 10. Selected Faecal-Oral Pathogens and their Transmission Routes[2]

Pathogen	Important Reservoir / Carrier	Transmission			X in Food
		Water	**Food**	**p-to-p**	
Campylobacter jejuni	Variety of animals	+	+	+	+
Salmonella typhi	Man and animals	±	+	±	+
Vibrio cholera, non OI	Man and animals	+	+	±	-
Cryptosporidium parvum	Man and animals	+	+	+	-
Giardia lamblia	Man and animals	+	±	+	-

X in food = multiplication in food
p-to-p = person to person
+ = yes ± = rare - = no

Table 11. Classification of water-related zoonotic diseases.

Category	Zoonotic	Remedial Measures
Waterborne via drinking water	*Salmonellosis, E. coli O157:H7, Cryptosporidiosis, Giardiasis, Campylobacteriosis, Microsporidiosis, Toxoplasmosis, Balantidiasis, Yersiniosis, Tularaemia, Cysticercosis*	Improve microbiological water quality through water treatment; protect drinking water sources from contamination by animal and faeces excreta
Waterborne via recreational water contact	*Leptospirosis, Cryptosporidiosis Giardiasis*	Protect water source from animal contamination
Water-washed	*Cryptosporidiosis, Giardiasis Balantidiasis*	Increase water quality to improve hygiene, promote hand washing and hygienic methods
Water-based	*Schistosomiasis (Schistosomajaponicum)*	Protect user, control aquatic hosts, surface water management
Water-related insect vectors	Yellow Fever Virus, Sleeping Sickness, Malaria, Dengue	Protect user, control vector, surface water management

Chikungunya,Filariasis and Testis flies that transmit sleeping sickness. The remedial measures include application of pesticides and destruction of breeding grounds and construction of piped water supplies and use of mosquito netsand domestic use of mosquito repellents.

Preventive and Remedial Measures

The faecal-oral infections are the most important cause of morbidity and mortality. The appropriate preventive strategy in each infection is discussed below:

1. **Water borne infection**:
   a. Quality improvement in drinking water
   b. Improvement in water use pattern and good hygiene
   c. Prevent use of contaminated water
   d. Proper storage and handling of drinking water to prevent recontamination risks
2. **Water washed infection**:
   a. Increased water use
   b. Improve use of soap in washing hands and hygiene standards
   c. Improvement in accessibility and reliability of water supply
3. **Water based infection**:
   a. Stop direct contact with step well water and bathing in surface water
   b. Reduce contamination of surface water by excreta (both livestock and human)
   c. Control Cyclops population to control guinea worms and snails to control Schistosoma
4. **Insect vector infection**:
   a. Better surface water management of tanks, talab, rivers etc.
   b. Control breeding sites of insects
   c. Use mosquito netting during sleeping hours
   d. Increase use of mosquito repellent
   e. Spraying of mosquitocides
   f. Covered storage of water

Stopping the open defecation is basic human requirement that must be basis for developing an organized society giving dignity to people. But for improvement of health, it is essential that livestock waste is also mitigated and controlled in open environment.

Safe Water Networkcommissions reverse osmosis plants in India with the purpose and objective to providing bacteriologically and chemically safe drinking water to the underserved population of India. It has been observed that bacteriological contamination is removed completely by the process adopted (sand filter, carbon filter, micron filter, RO membrane, UV disinfection and residual chlorine).

Despite the advanced water treatment technology and chlorination practices, the sub-standard water distribution system, intermittent water pressure due to power outages and other disruptions, and illegal connections in the distribution system often lead to the introduction of faecal contamination and therefore, microbiologically contaminated water at the consumer's tap or collection. In most of the cities, the sewer lines as well as drinking water pipeline run adjacent to each other and since water supply is generally scheduled for a few hours a day, it is empty for most of the time. This leads to flow of sewage into the drinking water lines through any leakage point that has developed over years in the distribution system due to aging of piping and joints. At some points people intentionally breach the drinking water pipe to extract water from it leaving it vulnerable for sewage contamination when there is no supply thereby zero pressure within the pipe. Due to this, the water supply is contaminated and unsafe. A further problem is that the water collected for domestic use often becomes re-contaminated by unsafe consumer storage and handling procedure at the household level. Factors contributing to this problem are unsanitary and inadequately protected container, water collection and storage containers, the user of unsatisfactory method to disburse water from household storage vessel including dipping of faecal contaminated hands / glasses. Lack of protection against contamination introduced by vectors such as flies, cockroaches and inadequate cleaning of vessels to prevent biofilm formation and accumulation of sediments and pathogens also leads to water recontamination. In order to overcome these problems and to find suitable, simple, acceptable, low cost interventions at the household, Safe Water Network has designed a water storage can made of virgin grade HDPE. The pouring is done by tilting the can and it does not require handling of water or putting one's hand inside to collect the water, as mouth of the can is about 46mm wide. This helps prevent recontamination of water, once treated and stored with residual chlorine.

CONCLUSION

The Government of India has increased grant for the construction of toilets under total sanitation campaign from INR 4,600 to INR 10,000 so that the toilets are used as toilets and not as store rooms done as earlier prevalent to control open defecation.

Livestock rearing is an important component in the rural India and domestic and commercial livestock are cows, buffalo, sheep, goat, pigs, rabbits, poultry etc. The cows and buffalos are main milk producing animals and constitute 59% of total population of India. India is the largest production of milk in the world.The total amount of dung produced in 1997 and 2003 was 270 and 268 million tons annually respectively. 50% of the cattle dung is used to make dung cake and remaining 50% is required to be suitably utilized or disposed. It has number of pathogenic organism which is responsible for zoonotic diseases and unfortunately India has topped in zoonotic diseases with widespread illnesses. About one third of global diarrheal diseases are attributed to zoonotic causes.

The microbes from dung are transported by variety of methods. First, some animals graze on pasture land and

Image4: A village woman pouring clean water from iJal container to her vessel for cooking purpose

Image 3: iJal 20-liter Water Container designed by Safe Water Network for its beneficiary communities in India

deposit manure directly on the surface of the agriculture levels or manure is applied to the field after storage and sometimes, even without prior storage. With precipitation, manure is converted into slurry, which transpires into the soil more readily and then attaches to the soil particles. Rainfall exceeding 20 mm per day can easily wash manure applied to the fields to adjacent water bodies or shallow ground water reservoirs / aquifers. The faecal microbes are reduced during the storage of manure prior to application, elimination of manure application associated with precipitation and maintenance of distance between farm and water bodies (surface or shallow ground water bodies) with buffer strips.

Microorganisms in livestock manure causes zoonotic diseases in humans include bacteria, protozoa, helminthic and virus. The bacterial pathogens are e. Coli, yersinaenterocolittica, salmonella, campylobacter, etc. The helminthic and protozoan pathogens includeascarissumm, ascarieslumbiriccodes, erypotospordium, and giardia. The viral pathogens are rotovirus, norovirus, avian influenza (H5N1). The main livestock are cattle, sheep, swine and poultry contributing to the above pathogens.

The per capita production of human faeces, urine and excreta is 120g, 1200g and 450g respectively in wet condition whereas in dry condition, their values are 50g, 60g and 110g respectively. The chemical composition of faeces is nitrogen (4.7%), phosphorous pentoxide (4%) and potassium oxide (1.6%). The urine has more nitrogen and potassium than faeces and faeces have more phosphorous than urine. The human excreta have more fertilizer value than pig and cow manure. Cattle excreta have more pathogens than human excreta.

The WHO has suggested that the faeces and urine production of 0.12 kg/capita/day and 1.2 l/capita/day for protein diet person,whereas in temperate and tropical climates, the vegetarian diet has faeces and urine contribution of 0.40 kg/capita/day and 1 litre/capita/day respectively for design purposes.

The infectious dose is the number of pathogens to cause infection. It is a proximate number of pathogens which depends on the environmental factors and health status of the individual, and the type of organisms. The pathogens die off exponentially upon excretion. Die off rates varies in proportion to the level of intensity of temperature, moisture, UV light and many factors.

Faecal coliforms and faecal streptococci ratio indicate the presence of animal and human pollution. The ratio of 4 indicates the pollution is of human origin and <0.7 indicates pollution of animal waste origin.The mode of transmission of the pathogens is water borne infection, water washed infection, water based infection, and insect vector infection. The faecal oral infections are the most important cause of mortality and morbidity. The appropriate preventive strategy includes quality improvement in the drinking water, improvement in water use pattern and improved used of soap in washing hands and hygiene standards, reducing contamination of surface water by excreta, stoppage of direct contact with the water bodies of animals and human, and control of breeding sites of insects.

Safe Water Network has installed many RO Plants at various villages. It is observed that bacteriological quality of drinking water is significantly improved and treated water is bacteriologically safe and residual chlorine is maintained at 0.2 mg/L. The treated water is also stored in a 20L jerry can which has a narrow mouth which does not permit recontamination of water through contact with hand.

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